

On Stone by G. Hawkins Junr from a drawing by Mr Charles Lewsey

Day & Haghe Lithrs to the Queen.

THE IRON BRIDGE OVER THE RIVER TRENT NEAR SAWLEY ON THE LINE OF THE MIDLAND COUNTIES RAILWAY.

PAPERS

ON SUBJECTS CONNECTED WITH

THE DUTIES

OF THE

CORPS OF ROYAL ENGINEERS.

R. E.

VOL. IV.

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INTRODUCTION.

Since the publication of the Third Volume of Professional Papers, the Corps of Engineers has to regret the death of an Officer, who, although withdrawn from the professional duties of the Corps, by those entailed upon him by his political situation, was yet ever active in forwarding its best interests. I need hardly mention the name of Drummond—he has left behind him a reputation which belongs not only to the history of the Corps of Engineers, but to that of his country. It is however in the capacity of a brother Officer that Captain Larcom has thrown together the brief notice of his professional career which is placed at the head of this volume; and I think in so doing he has conferred upon us a benefit for which our warmest thanks are due.

The other Papers composing the Fourth Volume require no particular notice. I trust they will not be found inferior in interest to those of the preceding Volumes.

W. D.

Woolwich, Dec. 28, 1840.

MEMOIR OF THE PROFESSIONAL LIFE

THE LATE CAPTAIN DRUMMOND.

No apology can be necessary for recording a few leading events in the professional life of a distinguished man; such events are the property of the body to which he belonged, and they remain when the individual is no more. Biography takes a wider range, a more sacred form: it preserves for the eye of affection and of friendship, the softer shadows of domestic life; it follows to the fireside, and delights to trace in the placid hours of relaxation and repose, the genius it has witnessed in its public flights. Such pleasing occupation is not the object of the present notice. It cannot dwell on private worth, or recall the days gone by; indeed, were it otherwise, the grateful office would be mixed with pain, the scenes revived would want their actors, and every pleasing reminiscence would come back clouded by the shadow of some friend since gone.

The subject of this Memoir is the late Captain Thomas Drummond, and the object with which it is placed here is an endeavour to show that talent and exertion need never despair of reward. Military habits and organization are conducive to the best interests of society, even during a period of the profoundest peace; and the duties of the Corps of Engineers in particular are of a nature which, in this age of general improvement, should always render its members useful to the community and the Government; but for this purpose exertion and study are necessary: the mere punctual performance of routine duties will never purchase distinction. It is eminently in this view the example of Captain Drummond may be useful, that it may afford hope and encouragement, and show that earnest devotion to professional pursuits is our best interest as well as our duty.

Captain Drummond was born at Edinburgh, in October, 1797. He was the second of three sons, and his father died while he was yet an infant, after which his mother removed to Musselburgh, a village in the neighbourhood, where she resided many years, devoting herself entirely to her children.

Among the strongest feelings of Captain Drummond's nature was the warmest affection for this excellent parent. He probably adds another to the many cases of remarkable men who owe their future greatness to a mother's care; and if this humble tribute to her son should ever meet that mother's eye, or be read by one to whom he was yet more closely connected,—in whose society his happy home gave a fresh impulse and relief to the arduous duties of his public life,—let pride in the memory of the departed be their common feeling. His mother's precepts formed a character of firmness, whose influence was felt through all the varying scenes of life; and when the world receded, its glories faded, and in the grasp of death distinction died, the effect of

the same mother's early culture again shone forth; for then appeared, when earthly clouds had vanished, its noblest fruit,—the clear unbroken light of religious truth. It would be unseemly here to dwell upon this solemn, sacred subject; but there is no moment of the life we record more replete with instruction, none more brilliant.

At a proper age Mr. Drummond was entered at the High School of Edinburgh, and there commenced an early acquaintance, which he ever afterwards sedulously maintained, with Professors Playfair, Leslie, Brewster, and with Professors Wallace and Jardine, whose pupil more especially he was.

In February, 1813, he was appointed to a cadetship at the Royal Military Academy at Woolwich, and he has often smiled at the terrors of his solitary entrance to this portal of his future life. It happened that, at a distance from Edinburgh and his family, he had no relative or friend to accompany and support him in the ordeal of examination; and when immediately on landing from the packet which had brought him from Scotland, alone, and with his letter of summons in his hand, he presented himself at the Barracks, the porter rebuffed him with the chilling information, "you are too late." He was received, however, and passed with credit. When once established, his mathematical abilities soon made him conspicuous, and it is remembered that he was moved from the sixth to the fifth Academy without the usual examination, and passed with such rapidity through that Academy, and the fourth and third, that at Christmas of the year in which he joined, he entered the second Academy. Here it perhaps was fortunate, that instead of being thus early launched into military life, a pause occurred, during the short peace from the summer of 1814 till the escape of Napoleon from Elba; after which, in July, 1815, he left Woolwich for the Corps of Royal Engineers.

Much of this success was doubtless to be attributed to the admirable preliminary education he had received, but much also to a character of determined perseverance, and to the vigorous and well-regulated mind he brought to bear on all subjects. To this it was probably due, that he never became exclusively a mathematician, but advanced equally in all the various branches of study, being at that time, as he continued through life, distinguished for general intelligence, and for aptitude to seize on information of every kind. His mathematical character at Woolwich has been thus well and justly sketched by his friend and master, Professor Barlow. "Mr. Drummond by his amiable disposition soon gained the esteem of the masters under whom he was instructed; with the mathematical masters in particular his reputation stood very high, not so much for the rapidity of his conception, as for his steady perseverance, and for the original and independent views he took of the different subjects that were placed before him. There were among his fellow-students some who comprehended an investigation quicker than Drummond, but there was no one who ultimately understood all the bearings of it so well. While a cadet in a junior academy, not being satisfied with a rather difficult demonstration in the conic sections, he supplied one himself on an entirely original principle, which at the time was published in Leybourn's Mathematical Repository, and was subsequently taken to replace that given in Dr.

Hutton's Course of Mathematics, to which he had objected. This apparently trifling event gave an increased stimulus to his exertions, and may perhaps be considered the foundation-stone of his future scientific fame. After leaving the Academy he still continued his intercourse with his mathematical masters, with whom he formed a friendship which only terminated in his much lamented death."

This remarkable combination was early appreciated by the admirable discernment of the Lieutenant-Governor, General Mudge, whose judicious encouragement it gained. In general conduct Mr. Drummond was exemplary, and it is remembered by the kind friend, Captain Dawson, to whose information this Memoir is largely indebted, that, when on the only irregularity recorded against him, an order—for the sake of discipline—announced some trifling punishment, the same order contained also an acknowledgment of his previous good conduct, and immediate forgiveness.

During his preliminary and practical instruction in the special duties of the Engineer Department, his talent for mechanical combinations became conspicuous, one of which is thus described by his contemporary and friend, Captain Dawson. "The various inventions to supersede the use of the old pontoon led Drummond himself to consider the subject, and he made a model, of a form like a man-of-war's gig or galley, sharp at both ends, and cut transversely into sections for facility of transport, as well as to prevent it from sinking if injured in any one part: each section was perfect in itself, and they admitted of being bolted together, the partitions falling under the thwarts or seats. The dock-yard men and sailors to whom he showed it, said it would row better than any boat except a gig, and it was to be light, and capable of being transported from place to place on horseback."

Several other inventions are remembered, showing the activity and readiness of his mind, and the interest with which he addressed himself to his new duties: but in reference to bridge-making, another anecdote may perhaps be preserved, being characteristic of other qualities. He was charged with the construction, for practice, of a bridge of casks, in the rapid current of the Medway at Rochester Bridge, and having previously made piers of the casks in the still water above the bridge, it was necessary to move them through the rapids to get them below the bridge. They were, as usual, lashed two and two for security; but one remained, and as its removal was likely to involve some danger, Mr. Drummond determined to go on it himself.

There were two soldiers on the pier, one of whom showed a little apprehension at setting off. Drummond placed this man next himself, and desired them both to sit quite still. They passed through the arch in safety, when the man who had previously shown apprehension, wishing by activity to restore himself to his officer's good opinion, got suddenly up to assist in making fast to the buoy: in an instant the pier upset, all hands were immersed in the water, and the man who had caused the accident, being on his feet, was thrown from the pier and drowned. Mr. Drummond and the other man clung to the pier, and Mr. Drummond afterwards described his sensations, when finding his body swept by the current against the under side of the pier, his last recollection

was a determination to cling to one side of it, in hopes the depression of that side might be noticed. This presence of mind saved him and his comrade, for as he had expected, a brother officer (Fitzgerald), noticing the lowness of one side, sprung from a boat upon the other, and immediately the heads of poor Drummond and the sapper appeared above the water. Drummond was senseless, with the ropes clenched firmly in his hands.

This early period of his career was also largely devoted to the acquisition of military knowledge, partly from the associations around him, and partly from the circumstances of the times. Jomini and Bousmard were his favourite authors, and often has the morning light surprised him in deep discussion on the details of Waterloo, and the strategy of the recent campaigns.

At Chatham a new world had opened on him: the practical application of varied and almost universal knowledge brought by Colonel Pasley to the aid of military science, offered the highest attraction to a mind like Drummond's: it was here also that he first became acquainted with Major, now Lieut.-Colonel Reid, whose talents and services he regarded with admiration, with whom acquaintance soon ripened to intimacy, and whose friendship he cherished to the last. The writer of this Notice has seen him in Ireland, in later years and amid other cares, dwell with animation and delight on the movements of the British Legion, in which Lieut.-Colonel Reid then held a command in Spain, and apply to the campaign the strategic rules and precepts he had gained from his early military reading.

During the period of his service at Chatham, his military fervour led him to obtain leave of absence for the purpose of visiting the army of occupation in France, and attending one of the great reviews. Many humorous adventures and difficulties in this first visit to a foreign country formed the subject of amusement afterwards, but he always remembered his tour in France, because it first brought him into acquaintance with his future friend and colleague, Major-General Sir John Burgoyne, then Commanding Engineer with a division of the army.

Before he joined at Chatham, he had served a short time at Plymouth, and after his Chatham course was completed, he was stationed at Edinburgh. The duties there offered nothing to engage his attention, relating merely to the charge and repairs of public works; but he was happy in being again thrown among his family and friends, and more, in the opportunity again afforded him of pursuing the higher studies in which he delighted, at the College and classes, and among the scientific society of his native city. He found the duties, however, so trivial, and the prospects of the service so disheartening, that for some time he meditated leaving the Army for the Bar, and had actually entered his name at Lincoln's Inn with this view.

But in the autumn of 1819 he fortunately became acquainted with Colonel Colby, when that officer was passing through Edinburgh on his return from the trigonometrical operations of a season in the Scottish Highlands. The opportunity which these duties afforded of combining scientific pursuits with the military service, induced him to abandon his intention of forsaking the Corps, and in the course of the following year an

offer from Colonel Colby to take part in the trigonometrical survey was gladly accepted. He had now the advantage of a residence during each winter in London, and now, with a definite object in view, he again devoted himself, and more closely than ever, to the study of the higher branches of the mathematics. For several years it was his constant custom to rise at four or five o'clock in the morning, and lighting his own lamp and fire, and taking a cup of coffee, study without interruption till eight or nine, when his official duties claimed his attention.

During this period he also devoted considerable attention to the study of Chemistry, and attended sedulously the morning lectures of Professors Brande and Faraday at the Royal Institution. The society of his friend Dr. Prout, it is believed, first led his mind to this noble science, and, with his usual felicity of application, he soon made his new knowledge available to the duties he was employed on. The incandescence of lime having been spoken of in one of the lectures, the idea struck him that it could be employed to advantage, as a substitute for argand lamps, in the reflectors used on the survey for rendering visible the distant stations; because, in addition to greater intensity, it afforded the advantage of concentrating the light as nearly as possible into the focal point of the parabolic mirror, by which the whole light would be available for reflection in a pencil of parallel rays, whereas, of the argand lamp, only the small portion of rays near the focus was so reflected. On this subject his first chemical experiments were performed. Captain Dawson recollects Drummond mentioning the idea when returning from the lecture, and that on the way he purchased a blowpipe, charcoal, &c.; that evening he set to work with these simple means, and resolved that he would thenceforth devote to his new pursuit the hour or two immediately after dinner, before his evening studies began, when, he said, he could do nothing else, remarking, "how much Dr. Prout had done during the intervals of active professional occupations."

At this period (1824) a Committee of the House of Commons recommended that the Survey of Ireland should be begun, and that Colonel Colby should make arrangements for carrying it on. The objects of this survey, destined to form the basis for a general valuation of the country, the public attention fixed on Ireland, and the numerous improvements in progress or in contemplation, required a work very different from the survey in England. The active mind of the chief, alive to the magnitude of his task, was accordingly directed to the necessity of means more extensive and more varied. Save himself and a small number of officers, every thing was to be formed for the work; three companies of selected sappers were allotted to the duty, but they had to be trained and organized for an operation so new to them. Instruments of improved construction were required, and great foresight was necessary to look forward to every probable want and contingency. Among others, a means of rendering visible distant stations was desirable; the recent experience of the Western Islands had shown the probability that in a climate so misty as Ireland, the difficulty of distant observation would be greatly increased; and Colonel Colby at once saw the important results which might follow such an improvement of the lamp as that which Drummond had devised: under his judicious advice the ex-

periments were prosecuted, and were rapidly attended with success; their progress and results are detailed by the author in the Philosophical Transactions for 1826, as well as the first application of the lamp to actual use in Ireland, when a station, Slieve Snaght, in Donegal, had long in vain been looked for, from Divis Mountain, near Belfast, the distance being 66 miles, and passing across the haze of Lough Neagh. Mr. Drummond took the lamp and a small party of men to Slieve Snaght, and by calculation succeeded so well in directing the axis of the reflector to the instrument on Divis, that the light was seen, and its first appearance will long be remembered by those who witnessed it. The night was dark and cloudless, the mountain and the camp were covered with snow, and a cold wind made the duty of observing no enviable task. The light was to be exhibited at a given hour, and to guide the observer, one of the lamps formerly used, an argand in a lighthouse reflector, was placed on the tower of Randalstown church, which happened to be nearly in the line at fifteen miles. The time approached, and passed, and the observer had quitted the telescope, when the sentry cried, "The light!" and the light indeed burst into view, a steady blaze of surpassing splendour, which completely effaced the much nearer guiding beacon. It is needless to add that the observations were satisfactorily completed, the labours of a protracted season closed triumphantly for Drummond, and the survey remained possessed of a new and useful power.

But it was not enough to facilitate observations by night; it was desirable also to possess the means of conquering by day the formidable obstacles of haze and vapour. For this purpose the principle of solar reflection had frequently been used, both in England and on the Continent; it is not easy to fix its date as an invention; the principle indeed is so familiar, and examples are so commonly presented to us in nature, that in some form or other it is probably coeval with the earliest geodetic operations of any considerable magnitude. In England, the earliest operation of this nature is that by General Roy in 1782, for connecting the meridians of Paris and Greenwich, when the smoke of London proved so formidable an obstacle to the observations proceeding across it, that the General is known to have resorted to this means of facilitating his observations. No record, however, has been preserved of the instrument he employed, or the mode in which he effected it. More recently, when in 1822 Colonel Colby and Captain Kater were employed in verifying this operation, they experienced the same difficulties, from the same cause, in observing Hanger Hill from Shooter's Hill; and they were on this occasion obviated by an ingenious contrivance of Colonel Colby (see Phil. Trans. 1828): it consisted of a stout plank, on the face of which were nailed, one below the other, several flat plates of polished tin, at angles calculated to reflect the sun's rays in the required direction, the plates being so computed, in reference to the relative position of the two stations and the sun, that they should keep up a tolerably continuous reflection for a considerable time, the rays being caught and thrown from each plate nearly as soon as by the motion of the sun they had left the plate above it.

Again, when in 1823 Colonel Colby had begun to carry a chain of triangles northwards to Cambridge for the purpose of fixing its observatory, Drummond was of the party: on

this occasion Wrotham Hill, in Kent, and Leith Hill, in Surrey, were to be observed from Little Berkhampstead, in Hertfordshire, and it was found as before, that the dense mass of smoke and fog which constantly envelope the metropolis defied all effort and all patience. Colonel Colby's apparatus was again resorted to, and with the same entire success. It was, however, somewhat elaborate, because from the rapid motion of the sun, or rather of the earth in its orbit, the same pole and set of plates would only answer for a single station, and for a short time on a very few days: the principle, however, was now obvious, and the elements which had been called into play soon suggested the more perfect instrument. From a calculation, of which the variables were the relative position of two stations and that of the sun, a happy step led to an instrument by which the problem should be, as it were, solved by construction,—a telescope in the line between the objects, connected with one to be directed on the sun, and carrying a mirror:—such, accordingly, was the first heliostat of Drummond; its mechanism is described in the Paper already referred to, (Phil. Trans. 1826,) and like the lamp it was used successfully in the first season of the trigonometrical operations in Ireland. It was originally intended to have given this instrument a divided circle, by which its direction could be fixed; but as this was not effected, a theodolite was necessary in conjunction with it, and practice soon showed that if a theodolite were used, a more simple and less costly heliostat might be adopted. This accordingly was devised by Mr. Drummond before the second season, the direction being effected entirely by the theodolite, instead of being, as before, dependent partly on the theodolite, and partly on the adjustments of the heliostat. The telescopes of the heliostat now became useless, and it remained a simple mirror, moveable in two directions, *i. e.* on a horizontal and on a vertical axis, of which the light was guided by a directing staff, previously placed by aid of the theodolite. This instrument proved so satisfactory that it has ever since remained the form adopted on the survey, and it is every season found more and more useful. By its aid several observations have been made at distances exceeding one hundred miles; and such is its facility of direction,—owing also, no doubt, in some degree to the great divergence which even the best mirrors give to reflected light,—that the theodolite is now frequently dispensed with; and by a few simple distances and measurements computed beforehand, a single soldier is sent with a heliostat to some remote mountain or island, with tolerable certainty that his reflection will be seen as soon as the sun shines after he reaches it.

This instrument, as well as the lamp, and the original heliostat, will be fully described and illustrated in the account of the base measurement, and other trigonometrical operations of the Irish survey, now in process of publication by Colonel Colby.

Mr. Drummond's original heliostat was not completed till 1825. A heliostat had been also invented by Professor Gauss, of Gottingen, in the process of a survey carried on by him in Hanover, where no doubt the same difficulties had been experienced: and perhaps it may be worthy of mention here, that a very simple heliostat had been used by the late Commander Mudge, of the Royal Navy, while surveying on the coast of Africa

in 1823-4, which consisted merely of a sextant sent forward to the station to be observed, and so adjusted as to throw the sun's light to the observer.

In the autumn of 1824, Colonel Colby made a general reconnoissance of Ireland, for the purpose of fixing on the mode of survey, the choice of stations for the great triangulation, and the most fitting place for a base. He selected Mr. Drummond to accompany him on this tour. The plain of Magilligan was chosen for the base, and Colonel Colby's attention was next directed to a fitting apparatus for the measurement. It is not intended here to offer an account of the new instruments, but it may be mentioned that Colonel Colby's long experience had shown him the defects of the apparatus formerly employed, and he boldly devised one altogether new, in which compensating expansions were to be used, to form an unalterable linear measure. The construction of the instruments required long and careful experiments, the charge of which was confided to Mr. Drummond; and so far as was necessary to prepare the instruments for use in the field, they were performed by him or under his direction. It occurred to him that mica, which had then recently been recommended by Sir David Brewster for pendulum-rods, might be applicable to this new purpose. Colonel Colby allowed experiments to be tried on that substance, but they were not satisfactory, and Mr. Drummond abandoned the idea. The apparatus was completed according to Colonel Colby's original plan, and successfully used in the base at Magilligan, of which the account is soon to be published. In the measurement Mr. Drummond was again employed, and whenever Colonel Colby was absent on other duty, the charge of the operations devolved on him.

At this period of invention and improvement, which preceded the commencement of the Survey of Ireland, Mr. Drummond gave some consideration to the barometer, an instrument even now susceptible of improvement, but which had not then received so much attention as it has since done. His favourite construction was the syphon, and he made one with his own hands, which performed remarkably well, but he was not in possession of various modes of reading which have since been used, some of which, especially Fortin's point, as now applied with a moveable scale by Newman, leave nothing to be desired, at least for the lower limb; and he devised a singular mode of bisecting a reflected image of the surface, a ghost as he called it, but he arrived at no permanent or practical result, and at length abandoned the subject, from a conviction, to use his own words, that the errors to which the barometer was liable from causes beyond control, were greater than the quantities he had been dealing with.

His researches on light, and his intimacy with Professor Leslie, led him to the use of the photometer, the æthroscope, and other philosophic instruments of more or less practical utility, among others, Wollaston's thermo-barometer: indeed, at this period, so active was his mind, and so constant his application, that scarcely an instrument existed which he did not examine and consider, with a view to render it useful for the purposes of the survey, and the elaborate collection with which the meteorological observatory on Divis was furnished, presented a singular spectacle on the mountain

top: he carefully observed and recorded them, till a calamitous storm destroyed the observatory and all its contents together.

The triumphant success which attended the lamp and heliostat at the close of 1825 has been mentioned, but this success was purchased at the cost of a severe illness. A mountain camp, at an altitude of two thousand feet, in the winter of these climates, is under any circumstances a severe trial, but Drummond and his little party were peculiarly exposed: few in number, being merely detached from the general camp on Divis, they were ill able to buffet with the storms of these wild regions; and the tents were so frequently blown down, that after the first few days they abandoned them, and constructed huts of rough stones, filling the interstices with turf. Such, without the additional luxury of a marquee lining, was the study and the laboratory on which depended the success of the new instruments: here were to be performed the delicate manipulations their adjustments required, here was to be manufactured the oxygen destined for the portable gasometer; and cowering over the fire, or wrapped in a pilot coat, was Drummond day and night at work. A frame and system attenuated by fatigue and excitement were ill able to bear up against such exposure: he struggled to the last, but no sooner had his efforts been crowned by success, than he sank, and a severe illness compelled him to return to Edinburgh, to the care of his family and friends. By the spring he was again in London at his post, but a distressing palpitation of the heart long remained to remind him of his winter camp on Slieve Snaght. During his stay in Edinburgh he was unable to devote himself to study, but he had taken much pains to perfect his apparatus; and he now began to revert to the idea he had early formed of adapting it to lighthouses. In this he was liberally met by the Corporation of Trinity House, and to it he devoted much of his time during the following winters: the experiments he made, with their success, are detailed in the Philos. Trans. for 1830.

The Corporation of Trinity House placed at his disposal a small lighthouse at Purfleet; and the brilliant effect of the light, as seen from Blackwall, where at a distance of ten miles it was sufficiently strong to cast shadows, made it an object of very general interest. The experiments were witnessed by many of the most distinguished persons in the country; and on one occasion His late Majesty, then Lord High Admiral, honoured it with his inspection.

But here his scientific career was to close; he had attracted notice, his talents had become known, and he was no longer destined to remain in the humble sphere of useful action to which his life had hitherto been devoted.

Here perhaps it may be proper to notice the erroneous ground on which Mr. Drummond has often received credit for the lime light. He has been by some called the inventor or discoverer of this brilliant light, and when it is found to have been known before, he is by others accused of piracy. He never claimed the chemical discovery; it has been seen to have grown out of a lecture on the very subject, and it is known that the solar microscope had been exhibited several years before at the London Institution, and probably at other places, by the light of lime burnt under the mixed gases.

Mr. Drummond's merit was in rendering practically useful a recondite experiment,—by devising a means of procuring and using without danger agents so turbulent as the mixed gases, making the apparatus sufficiently portable and simple to be employed in the circumstances of exposure required for the survey, and perhaps more than all, for the happy idea of using this minute spherule of concentrated light as the radiating focus of a parabolic mirror.

Thus much for the lamp as used for geodetic purposes, its original object; its application to lighthouses presents difficulties which have yet to be overcome. The abstraction of Mr. Drummond's attention at the moment he was nearest to success, must, so far as the light is concerned, be considered matter of regret: with its projector it has dropped, but if it be practicable, ingenuity will doubtless sooner or later be directed to render it available, and the Drummond light may yet cheer the home-bound mariner from the Great Skellig or the Tuskar.

We now arrive at an important epoch in Mr. Drummond's life: his duties and pursuits heretofore had been wholly professional; and although the natural intelligence of his mind had constantly led him to other subjects, and other branches of science, he was always on the alert to convert the knowledge he gained to professional purposes. From all such excursions he brought back something to the hive; but his power of application was immense, and the avidity with which he pursued any object to which his attention was directed, can be known only to those who witnessed it. He had insensibly amassed a store of general knowledge, and required a larger field for its developement. At this time (1831) the Reform Bill was introduced, and much statistic and other local information was required by the Government in its progress.

This was Mr. Drummond's first political occupation, and his employment on it is due to his friend Mr. Bellenden Ker, who mentioned him to Lord Chancellor Brougham. That great man having already met him, in witnessing his Light experiments, and as a Member of the Council of the Society for diffusing Useful Knowledge, was prepared to think favourably of his abilities; and after sending for him, and discussing the subject, had no hesitation in proposing him to the Government for the distinguished post in which he was placed at the head of the Boundary Commission. The original instructions for this Commission are printed in the Parliamentary Papers, dated 8th August, 1831, and considerable progress had been made in the inquiry, when the dissolution of Parliament caused an important change, by introducing a consideration of the taxes paid, in addition to the number and value of the houses within the boroughs, as elements for determining their places in the scale of representation. The manner in which Mr. Drummond combined these considerations is explained by himself in his letter to Lord Melbourne, dated 12th December, 1831, and has been thus simply stated by Professor Barlow. "Parliament having decided that the importance of the several boroughs should be made to depend upon the number of houses and the amount of assessed taxes conjointly, and houses and taxes being incongruous quantities, it was necessary to establish abstract values for each, whereby the two claims might be combined. In order

to this the following rule was adopted, viz.: First, as the whole number of houses in all the boroughs is to the number in any given borough, so is unity to the decimal expressing the importance of the borough as regards the number of its houses: and, in like manner, as the whole amount of assessed taxes in all the boroughs is to the assessed taxes in any given borough, so is unity to the decimal expressing the importance of the borough as regards assessed taxes. Having thus obtained two series of abstract numbers denoting the relative importance of the several boroughs, the numbers for each were added together, and a new list formed according to their combined claims, and according to which the boroughs were finally arranged."

Mr. Drummond entered on this employment contrary to the advice of many of his friends, who regretted he should engage in any occupation which should divert his mind from the pursuit of science; but he had no hesitation himself, and to his honour be it said, that from the time of his appointment to the Boundary Commission to the day of his death, he was distinguished by the intimacy and friendship of his great patron, the Lord Chancellor.

The announcement of a Reform Bill, by which parliamentary representation was to be based on scientific principles, was new and startling, and it cannot be matter of surprise that much clamour and many absurd objections assailed the calculations; but these, though they caused much annoyance and pain to Mr. Drummond, wholly inexperienced as he was in party politics, were of course easily defeated: here, as in the lamp, the real merit was mistaken, and a claim to strict mathematical precision was assumed to be set up. Such claim it had not. On this point his friend Professor Barlow speaks what were Mr. Drummond's own views when he says, "Nothing can be conceived more equitable, but it can scarcely be considered as a principle admitting of mathematical demonstration. The only mathematical idea in the rule was that of exhibiting the claims of each borough, under each head, in abstract numbers, so as to allow of their being added together, for general arrangement. It has, in fact, the same relation to mathematics, which equity has to law."

The long and severe parliamentary contests which attended the passing of the Reform Bill are recent and well remembered. It required all the energy and all the application for which Mr. Drummond was so remarkable, to prepare the data, and meet the objections to his calculations: toilsome days and sleepless nights; the Home Office in the morning, and then the House; and, after the division, often no sleep till he had satisfied himself the objections which had been raised were futile, and till fresh evidence was prepared to bear upon the doubtful points.

Every borough the subject of a contest, even some high names in science, for a moment ranked against him; but, some convinced, and some defeated, the Bill at length was carried; and the writer of this Notice well remembers the calm and solemn feeling with which, the morning after the third reading in the Lords, Drummond stood and summoned to memory a brief review of all its stages, pausing from time to time where objections had been made to his own labours, and finally dismissing all with the firm

conviction he had done his duty to the Government, and aided a cause he conscientiously adopted as his own.

The reaction from this severe labour was, as usual, illness and exhaustion. Brighton and its air, and exercise, recruited him; but more than this, was the heartfelt joy he received from the approbation and friendship of his brother Commissioners. His task had been one of much delicacy as well as labour, and of all the compliments which awaited him, none was more gratifying than the letter addressed to him by the gentlemen with whom he had acted in the Boundary Commission. The letter is as honourable to those by whom it was written, as to him to whom it was addressed, and it would be less than justice to give it otherwise than entire. The portrait it requests was painted by Pickersgill, and presented by Mr. Drummond to his excellent mother: from this picture an engraving is now in process of execution by Couzens.

DEAR DRUMMOND, London, June 6, 1832.

We, who have been your fellow-labourers in the task intrusted to us by the Government, of recommending the proper limits for Boroughs under the Reform Bill, entertain an anxious desire, before we separate on the completion of our labours, to express to you in some marked manner our esteem and admiration of your conduct of that work.

We entertain no doubt that the Government will take the earliest opportunity of adequately discharging the great obligations it owes you, which can be duly appreciated only by considering the consequences if they had found in you any thing short of the most perfect integrity, the most active zeal, and the most acute intelligence.

But something would be still wanting to our own feelings, were we not to contrive some method of denoting our sense of the sound judgment and amiable manner which has marked your whole intercourse with us, making it a source of pleasure to ourselves, and contributing in no small degree to the perfection of the harassing duty in which we have been engaged.

After much consideration on the most appropriate method of recording these feelings, we have resolved to request that you will do us the favour to sit for your portrait to one of the best artists of the day.

We hope this will be preserved in your family as a memorial of the sense entertained of your merits by a number of gentlemen who have acted with you in the execution of a delicate and arduous duty, intimately connected with an important event in the history of our country.

We remain, Dear Drummond,

Your attached friends,

E. J. LITTLETON.
F. BEAUFORT, R.N.
L. B. ALLEN.
B. ANSLEY.
THOS. B. BIRCH.
H. R. BRANDRETH.
J. J. CHAPMAN.
R. D. CRAIG.
ROBERT K. DAWSON.
J. ELLIOTT DRINKWATER.
J. F. ELLIS.
HENRY GAWLER.
H. BELLENDEN KER.
HENRY W. TANCRED.
G. B. LENNARD.
W. H. ORD.
JOHN ROMILLY.
ROBERT SAUNDERS.
RICHARD SCOTT.
R. SHEEPSHANKS.
W. EDWARD TALLENTS.
JOHN WROTTESLEY.
W. WYLDE.

The Reform Bill became law. The Commission was dissolved, and Mr. Drummond again for a time returned to the duties of the Survey. It was his task to prepare for publication an account of the base already adverted to, and he had commenced a

synoptic view of former bases, with a brief notice of their merits and defects, preparatory to his own account. This had led him to Probabilities, and La Place was, it is believed, his last mathematical reading. Additional experiments were required for the comparison of the new standards with those formerly used, and it was necessary to await the final decision of the legislature on the actual standard,—a decision not yet come to,—before the account should be published; when Mr. Drummond, by a new call to public life, was again and finally removed from scientific pursuits and exact knowledge, to a sphere in which moral chances were to take the place of physical, and in the hope of ameliorating the condition of future ages, he was to share the labours and the anxieties of the statesman and politician.

Among the distinguished persons to whom he had become known by the Reform Bill was Earl Spencer, who, as Lord Althorp, was then Chancellor of the Exchequer, and led the nation in the House of Commons. That nobleman now offered Mr. Drummond the situation of his Private Secretary, which was willingly accepted. The duties of this office gave him much valuable insight into the details of public life, but were chiefly useful in enabling him to cement the esteem in which he was held by the members of the Government, and by none more than his noble chief, to whom the clearness of his conceptions, and the straightforward honesty of his mind, were eminently congenial. No greater compliment can be recorded than that Lord Spencer is stated to have said, "one of the most pleasing recollections of his political life was, that it had made him acquainted with Mr. Drummond."

The sudden dissolution of the Government in 1834 again threw Mr. Drummond for a time aside, but on this event a pension of £300 a year was granted to him, which, it is understood, his constant friend Lord Brougham was instrumental in obtaining, and the grounds of which are thus stated in the Report of the Select Committee on Pensions, dated 24th July, 1838.

"Lieutenant Drummond was a distinguished officer of the Royal Engineers, whose abilities had been shown, not only in the trigonometrical survey of Ireland, and the more peculiar branches of his profession, but in the prosecution of various branches of science, in which he has made useful and interesting discoveries. He was employed by the Government of Lord Grey in procuring the statistical information on which the Reform Bill was founded, as well as in determining the boundaries of districts and boroughs. Those services were rendered gratuitously: he was afterwards employed in preparing the Bill for the better regulation of Municipal Boroughs. Finally, he was employed from April, 1832, to April, 1834, as Private Secretary to Lord Althorp, Chancellor of the Exchequer."

This pension, granted in 1834, Mr. Drummond drew till the 30th September, 1835, but never afterwards. On the return of his party to power he was sent, in July, 1835, as Under Secretary with the Earl of Mulgrave to Ireland. His career was now become political, and this Memoir might perhaps with propriety and justice close. The period yet to come was doubtless the most important of his life, is that whose results will

remain the longest, and is probably that by which he will be principally known hereafter, at least in Ireland. Greatly were it to be wished that some contemporary would record them: there is perhaps but one fitted for the task by daily intimacy, one to whom every circumstance connected with the Government is known,—the confidential legal adviser: the higher duties of that officer may, it is feared, now prevent it, but the man who records the virtues of another erects a monument to himself.

Some occupations, however, in degree professional, especially the Railway Commission, remain; these briefly demand our notice.

In August, 1835, the meeting of the British Association was held in Dublin, but in the din of politics which now echoed round him he found an atmosphere uncongenial to his former studies, and he was seldom seen among the men he had formerly esteemed the most.

In 1836 the Bill for Municipal Reform in Ireland was introduced into Parliament, and it was necessary that the several boroughs should be visited, and boundaries fixed on for them. Mr. Drummond had been employed on the similar Bill for England, and he entered warmly into the subject now, but confided its execution to Captain (now Lieut.-Colonel) H. D. Jones, and twelve other officers of Engineers. The instructions were drawn up by Mr. Drummond, and they contained the peculiarity of fixing a time at which the reports and plans should be completed: it may also be added, that so fully was the energy of his spirit felt, that this Commission exhibited the still greater peculiarity of being complete by the time appointed, and for a smaller sum than had been estimated as its expense. Mr. Drummond's personal attention was of course directed to the political principle of this remarkable Bill, being one of those most vexed by party; and it may perhaps be remarked, that its tendency to localize and distribute power appears to have been somewhat overlooked by a recent writer, when he elsewhere dwells on the general effort of the present Government of Ireland to develope the Norman as opposed to the Saxon principle of the constitution. To the former principle the habits of a soldier may naturally be thought to incline, and so far, therefore, as the opinions of a humble functionary may influence the guiding power above him, Mr. Drummond's weight was probably felt in centralization, but he was too well read in medi-æval history to slight the influence of municipia.

Among the early objects which engaged Mr. Drummond's attention in Ireland was a plan for abolishing the hulks at Cork and Dublin, which received the convicts previously to their transportation; and removing them at once from the gaols to the vessels which carry them abroad. He was in this ably assisted by Captain Brandreth, R. E., who, with instructions from Lord John Russell, was sent to Ireland for the purpose. Captain Brandreth was strenuously supported by Mr. Drummond, and on his report and plans it is believed the system was abolished, and that which prevails was substituted.

In October, 1836, the Irish Railway Commission was constituted, and in this Mr. Drummond was personally occupied as First Commissioner. It demanded, indeed, a combination of qualities in its members which few subjects require. The construction

of a road is simple, its direction is a more complicated question; but when the road is to be used for a new and improved locomotion, and its direction not a single line from point to point, but a series of lines diverging from the capital, and destined with the smallest length to traverse the greatest space of country, the difficulties of the problem vastly increase;—when instead of following events they precede them; when instead of providing for a traffic or an intercourse already existing, they are to be laid out with a view to one yet to come, and in whose creation they are, by a sort of inverted parentage, to bear a part:—by these conditions we add to the forethought necessary—when instead of a country with established industrial channels, they are in one almost new in such respect; yet not new as a colony is, but abounding in vested interests:—where capital is not deficient, but where its investment in useful works had rarely proved advantageous or secure;—hailed with acclamation, but watched with jealousy;—with sufficient Government support to give it weight, yet depending on public approval for ultimate success;—it was obvious at its opening that the Railway Commission had no easy duty to perform. The selection of the Commissioners was accordingly of the last importance. In Sir John Burgoyne, Chairman of the Board of Works, the public had long recognised high integrity and sterling judgment, and in him they naturally saw the executive head of the future roadway system; in Professor Barlow, the representative of the science of the day; in Mr. Griffith, the geologist of Ireland, and her leading practical engineer during a quarter of a century, who had traversed every nook and river and roadway, descended her mines, and explored her mountains, to whom were alike familiar the structure and the surface of the island. At the head of this distinguished union was placed Mr. Drummond.

The conclusions at which they arrived are now before the public, and it would be superfluous to do more than point to their Report, which, when enthusiasm and prejudice have passed alike away, will always remain a monument of industry, science, and good sense,—a digest of all that can be said on the subject,—a valuable boon therefore to the Government, to the Nation, and to Ireland in particular. The master-mind will be seen in its grasp and arrangement; the pervading knowledge, in the correctness, the completeness, the minuteness of its details. In the First part, the circumstances to be observed in laying out a system of railways in Ireland; the Second, scientific principles and expense; the Third, the interest which the public have in their construction. The reader may easily discover the chapters and sections which have emanated from the several distinguished members, but he will perceive no individual opinion. While every subject is in itself complete, the judgment of all is evident in each.

It is not intended here to analyse or enlarge on this Report; a general notice of it has been rapidly given, only that the magnitude of the subject may be felt, in justice to the indefatigable exertion of the individual who, in the arduous duties of an arduous office, at a most critical time,—the Secretary of the Government in Ireland under Lord Mulgrave,—could yet encounter such a task. Mr. Drummond's faculty of transacting such a mass of business was due to a remarkable power of concentration, by

which he could fix the whole force of his mind on the subject in discussion, to the utter exclusion of every other; whether the subject were great or small, his mind appeared to grasp, and could not be diverted from it. This power, in his case, was doubtless vastly strengthened by discipline, and by mathematical and professional studies; but, whether natural or to be acquired, there is no power so valuable, perhaps so indispensable, to success in high employ. To such a mind, to will and to do were one; but nature claimed her rights. The Railway Report was presented in 1838; and, as on former occasions, the work performed, the body sank.

A short tour was all the respite his official duties would allow: he returned from the continent somewhat restored; but those who had known him long, and saw him now, began to mark the ashy cheek and sunken eye. When he undertook the Railway Commission he was in physical strength unequal to the task, and he never recovered that fatal addition to his labours; of those labours some view may be formed from a perusal of his examination before the Committee on Crime in Ireland, in the year 1839. He returned, however, to business with his usual avidity, and in the winter his health again became visibly impaired, and he was again induced for a short time to retire. But the scene was about to close; illness succeeded illness, each inconsiderable, but together showing, that while the mind increased in grasp and power, and from every exercise and every conquest sprung yet to loftier effort, mortality prevailed, and strength declined. At length, on the 15th of April, 1840, in the plenitude of mental power and the maturity of knowledge, beloved in private, and esteemed in public life,—he sank,—undimmed by failure, unclouded by reverse.

For the example and imitation of his brother officers this Notice is submitted. In death we claim our brother, and step forward to support his bier. We presume not to approach the sanctuary of private grief, to lift the veil that shrouds the mourner; but the scene which marked the funeral honours of our friend must not go unrecorded. He died for Ireland,—to us his professional career had already closed. The scientific soldier had become the philosophic statesman, and his funeral beseemed the latter. No military display was there,—the pomp of martial woe was merged in the demonstration of popular regret. Appalled by the sudden blow, a general grief prevailed, and the city poured its thousands through the streets in one prolonged procession,—the private friend, the public colleague, the high and noble of the land; and—in no vanity be it said, but in respectful gratitude recorded—the remains of the once humble soldier were followed to the grave by the Representative of his Sovereign.

P. S. It may perhaps with propriety be mentioned here, that since this Memoir was written, a subscription has been raised, and a large public meeting has awarded to our friend the posthumous honours of a statue. It will be executed in Rome by the celebrated HOGAN, at a cost of £1200, and be placed in one of the principal public buildings of Dublin.



PROFESSIONAL PAPERS.

I. (A.)—*Letter from Captain* George Thomson, *E. I. C. Engineers, to Colonel* Pasley, *Royal Engineers.*

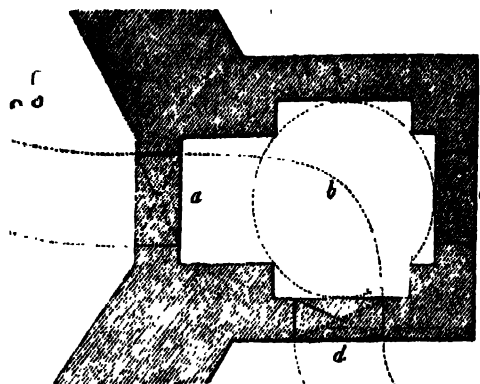
Camp Cabul, 15th August, 1839.

Dear Sir,

Feeling assured that you take an interest in the proceedings of the Engineers of the Indian Army, I have the pleasure to enclose the copy of a memorandum of the Engineer operations at the taking of Ghuznee last month; with a rough sketch of the Cabul gateway which was blown open. The former having been submitted to His Excellency Sir J. Keane, the commander-in-chief, and approved of by him, may be considered an authentic document; but the sketch was made very hurriedly, and may not be correct; I have therefore added a view of the gateway by Lieutenant Durand, See Plate I. which is exact.

With reference to the quantity of powder used in blowing open the gate, I beg to explain that though we were aware of the wicket being open, from seeing men pass in and out, yet we were not at all certain that the gateway had not been partly blocked up: there was certain information that the other gates had a quantity of large stones piled against them, and it required but a couple of hours to have closed the Cabul gateway in the same manner.

It was also uncertain whether there was not an inner gate; and had there been one, opposite to the outer, the 300 lbs. of powder would probably have cleared away both. But a second party of sappers, with 300 lbs. more, was ready in case any obstacle had been met. However, the archway in which the second gate had been formerly, was found built up, the arch having cracked, and an opening made to the right; in it there were fastenings for a gate, but none hung. The entrance was like this.



a—the gate.
b—domed building.
c—closed gateway.
d—new gateway.

The turn in the passage prevented the fragments of the gate being blown clear, and they were much in the way of the progress of the assaulting column.

The gate was so completely destroyed that its construction could not be ascertained, but it is supposed to have been a strong frame with rather weak planking, as the light in the guard-room was seen through the joints by Lieutenant Durand when he laid the powder. The timbers running into the wall on each side were about a foot square scantling, they were broken off short and clean, almost as if they had been sawed. The piers of the arch outside the gate were shattered and partly brought down; and the flat roof of the passage, leading from the gate to the domed portion of the building, was partly blown off, being very slight.

The ignorance of the garrison was much in our favour; they had never heard of a gate being blown open by powder, and the panic which seized them enabled the head of the column to gain an entrance without loss; the cowardice of their chiefs, Hyder Khan the governor being the first to run, prevented any effectual resistance to the column, though its progress was retarded by the rubbish in the gateway.

Altogether the attack was more successful than could be anticipated in future attempts of the kind.

Should you think the subject likely to prove generally interesting, the Editor of the Engineer publication lately established is welcome to a copy of the Papers.

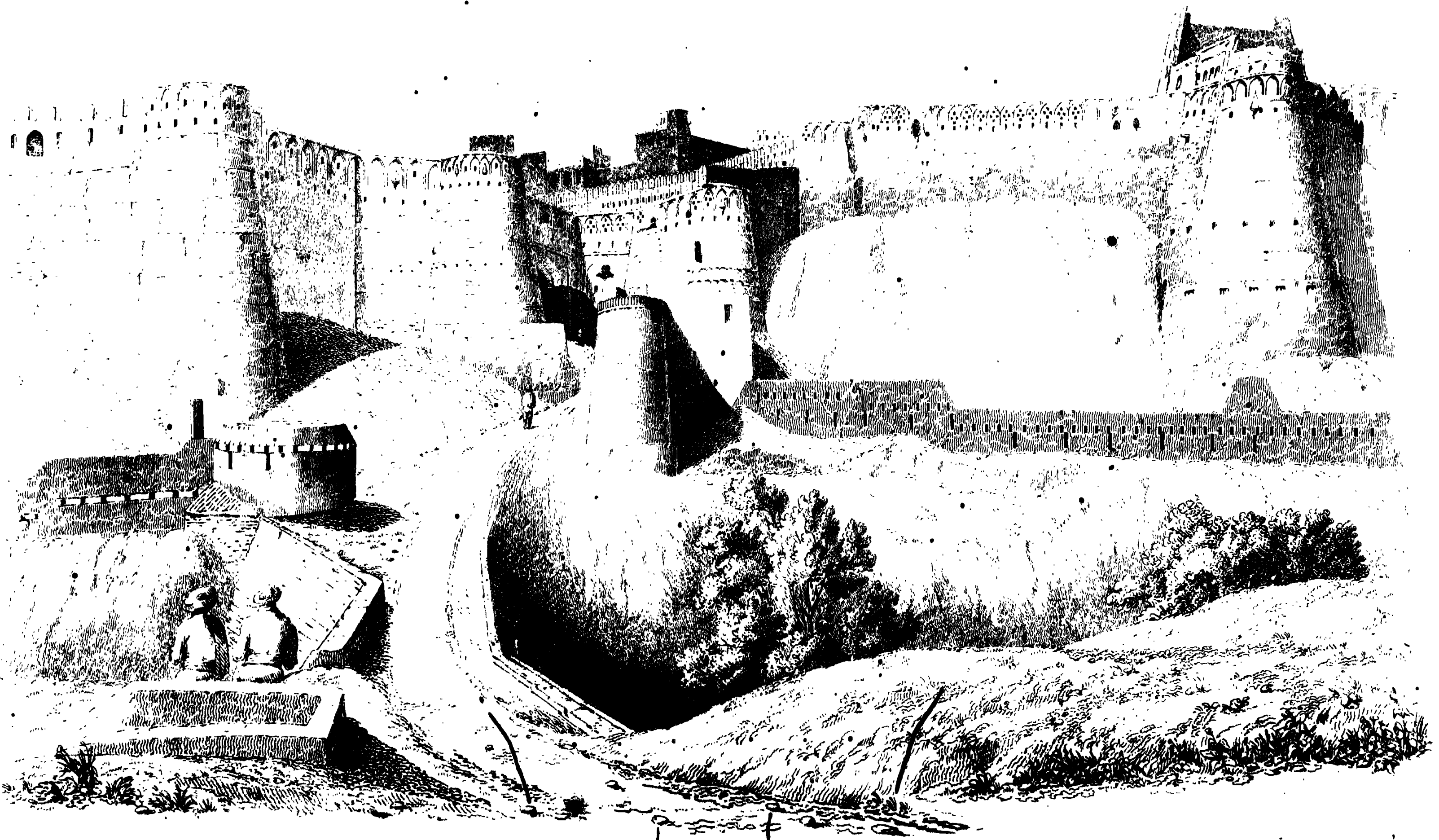
I remain, dear Sir,

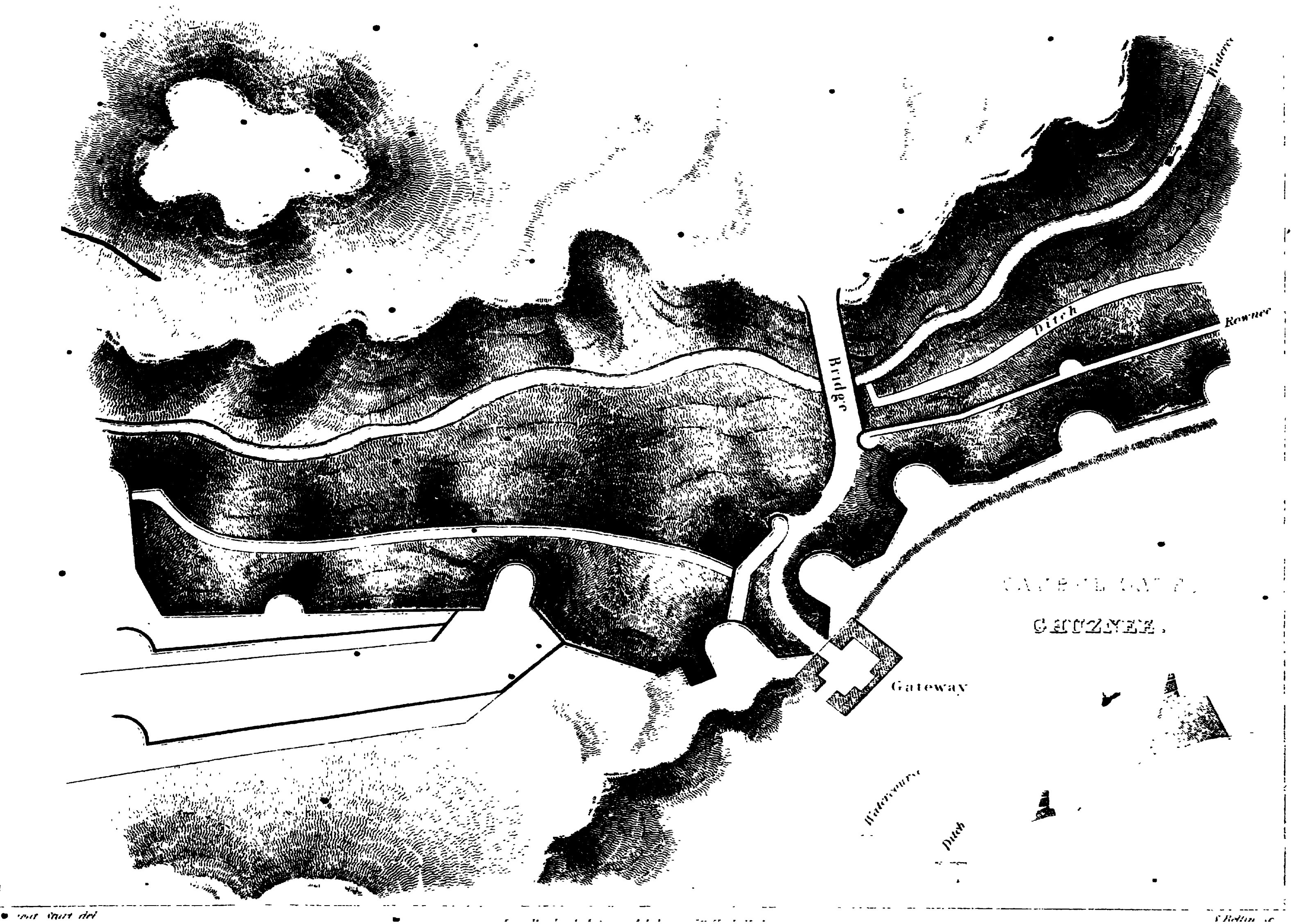
Your obedient servant,

George Thomson,
E. I. C. Engineers.

CAUBUL GATE OF GHUZNEE.

from a sketch by Lieut.t Durand, Royal Engineers





GHUZNEE.
Bridge
Ditch
Gateway
Watercourse
Ditch

I. (B.)—*Memorandum of the Engineer Operations at the Taking of Ghuznee, in July*, 1839.



The accounts of the fortress of Ghuznee, received from those who had seen it, were such as to induce His Excellency the commander-in-chief to leave in Kandahar the very small battering train then with the army, there being a scarcity of transport cattle. The place was described as very weak, and completely commanded from a range of hills to the north.

When we came before it on the morning of the 21st July, we were very much surprised to find a high rampart in good repair, built on a scarped mound about 35 feet high, flanked by numerous towers, and surrounded by a fausse-braye and a wet ditch. The irregular figure of the enceinte gave a good flanking fire, whilst the height of the citadel covered the interior from the commanding fire of the hills to the north, rendering it nugatory. In addition to this the towers at the angles had been enlarged, screen-walls had been built before the gates, the ditch cleared out, and filled with water (stated to be unfordable), and an outwork built on the right bank of the river, so as to command the bed of it. The garrison was variously stated from 3000 to 4000 strong, including 500 cavalry; from subsequent information we found that it had not been over-rated.

On the approach of the army a fire of artillery was opened from the body of the place, and of musketry from the neighbouring gardens. A detachment of infantry cleared the latter, and the former was silenced for a short time by shrapnells from the horse artillery. But the fire from the new outwork on the bank of the river was in no way checked. A nearer view of the works was however obtained from the gardens, which had been cleared. This was not at all satisfactory; the works were evidently much stronger than we had been led to anticipate, and such as our army could not venture to attack in a regular manner with the means at our disposal. We had no battering train, and to

attack Ghuznee in form, a much larger train would be required than the army ever possessed. The great height of the parapet (60 or 70 feet above the plain), with the wet ditch, were insurmountable obstacles to an attack merely by mining or escalading.

It therefore became requisite to examine closely the whole contour of the place, to discern if any other mode of attack could be adopted. The engineers, with an escort, went round the works, approaching as near as they could find cover; the garrison were on the alert, and kept up a hot and well-directed fire on the officers whenever they were obliged to show themselves. However, by keeping the infantry beyond musket range, and the cavalry at a still greater distance, only one man was killed and one wounded, and the former was hit by men sent out of the place to drive off the reconnoitering party.

The fortifications were found equally strong all round; the only tangible point observed was the Cabul gateway, which offered the following advantages for a coup-de-main: the road up to the gate was clear, the bridge over the ditch was unbroken, there were good positions for the artillery within 350 yards of the walls on both sides of the road, and we had information that the gateway was not built up, a reinforcement from Cabul being expected.

The result of this reconnoissance was a report to His Excellency the commander-in-chief, that if he decided on the immediate attack of Ghuznee, the only feasible mode of attack, and the only one which held out a prospect of success, was a dash at the Cabul gateway, blowing the gate open by bags of powder.

His Excellency decided on the attempt, the camp was moved that evening to the Cabul road, and next morning (the 22nd) Sir John Keane in person reconnoitered the proposed point of attack; he approved of the plan, and gave orders for its execution. Preparations were made accordingly, positions for the artillery were carefully examined, which excited the jealousy of the garrison, who opened a smart fire on the party.

It was arranged that an explosion party, consisting of 3 officers of Engineers (Captain Peat, Lieutenants Durand and Macleod), 3 sergeants, and 18 men of the sappers, in working dresses, carrying 300 lbs. of powder in 12 sand-bags, with a hose 72 feet long, should be ready to move down to the gateway at daybreak. At midnight the first battery left the camp, followed by the other four at intervals of half an hour. Those to the right of the road were conducted to their positions by Lieutenant Sturt, of the Engineers, those to the

left by Lieutenant Anderson; the ground for the guns was prepared by the sappers and pioneers, taking advantage of the inequalities of the ground on the right, and of some old garden walls on the left. The artillery were all in position and ready by 3 A.M. of the 23rd, and shortly after, at the first dawn, the party under Captain Peat moved down to the gateway, accompanied by 6 men of H. M. 13th light infantry without their belts, and supported by a detachment of the same regiment, which extended to the right and left of the road when they arrived at the ditch, taking advantage of what cover they could find, and endeavouring to keep down the fire from the ramparts, which became heavy on the approach of the party, though it had been remarkably slack during the previous operations. Blue lights were shown which rendered the surrounding objects distinctly visible, but luckily they were burned from the top of the parapet, instead of being thrown into the passage below.

The explosion party marched steadily on, headed by Lieutenant Durand; the powder was placed, the hose laid, the train fired, and the carrying party had retired to tolerable cover in less than two minutes. The artillery opened when the blue lights appeared, and the musketry from the covering party at the same time; so quickly was the operation performed, and so little were the enemy aware of the nature of it, that not a man of the party was hit.

As soon as the explosion took place, Captain Peat, though hurt, his anxiety preventing his keeping sufficiently under cover, ran up to the gate, (accompanied by a small party of Her Majesty's 13th light infantry,) and ascertained that it was completely destroyed. There was some delay in getting a bugler to sound the advance, the signal agreed on for the assaulting column to push on, and this was the only mistake in the operation.

The assaulting column consisted of four European regiments, commanded by Brigadier Sale. The advance under Lieutenant-Colonel Dennie, accompanied by Lieutenant Sturt, Engineers, moved steadily through the gateway; though a passage inside the gate, ending in a domed building with the opening on one side, made every thing very obscure, and rendered it difficult to find the outlet into the town. They met with little opposition; but a party of the enemy seeing a break in the column, owing to the difficulty in scrambling over the rubbish in the gateway, made a rush sword in hand, and cut down a good many men, wounding the Brigadier and several other officers. These swordsmen were repulsed, and there was no other regular opposition; the surprise and alarm of the Governor and Sirdars being so great when they

saw the column occupying the open space inside the gate and firing on them, that they fled, accompanied by their men; even the garrison of the citadel following the example. Parties of the Afghans took refuge in houses, firing on the column as it made its way through the streets; and a good deal of desultory fighting took place in consequence, by which some loss was sustained. The citadel was occupied as soon as daylight showed that it had been evacuated by the enemy, and the whole of the works were in our possession before 5 o'clock.

We lost 17 men (6 Europeans and 11 natives) killed; 18 officers, 117 Europeans, and 30 natives, wounded; total 182. Of the Afghans more than 514 were killed in the town, that number of bodies having been buried, and about 100 outside by the cavalry; 1600 prisoners were taken, but I have no means of estimating the number of wounded.

There were nine guns of different calibres found in the place, a large quantity of good powder, considerable stores of shot, lead, &c., and a large supply of Otta and other provisions.

George Thomson,
Captain, Chief Engineer, Army of the Indus.

II.—*Notes on Brixen and Verona in* 1838. *By* T. K. STAVELEY, ESQ., *late Captain Royal Engineers.*

THESE two fortresses, though distant from each other 120 miles, will be considered together, and first in a strategic point of view, as intimately connected with the defence of the Tyrol and the Austrian possessions in Italy.

In conjunction with the valley of the Danube (and more particularly in 1799), the Tyrol and Lombardy have been the theatres of the campaigns of the French against the Austrians. The latter power, assisted by the Russians in that year, had the advantage, but great inconvenience was felt from the want of some central depôt, from whence her troops could receive regular supplies, and which, from its strength, should secure the lateral communication between the armies on the Danube and in Lombardy.

Switzerland having been generally open to France, the first defensive line of the Austrians has been from the Danube, near Ulm, by Bregens and the valley of the Upper Rhine, thus preserving a communication with Italy by the route of the Splugen, which has of late years been much improved and made a great road. So long as they are successful on the Danube and in Italy, the favoured country of the Tyrol may be considered as secure; but in case of reverses, the want of a point of support on which to fall back has always been much felt, and for this purpose the Archduke Charles recommended the following places to be occupied by strong fortifications, viz., Ulm, Ingoldstadt, Ens, Brück-Villach, Brixen, Trente, and Verona. Whatever may be the merits of these places in a strategic point of view, the present Paper must necessarily be confined to the fortresses of Brixen and Verona, which have been chosen by the Austrians for two fortified points.

The following extract from the "Campagne en 1799, en Allemagne et Suisse," will show at once the great importance of Brixen. "En fortifiant

" Brixen, où se croisent les grandes routes du Tirol, on peut se dispenser de " porter des corps considerables jusqu'aux frontières de cette province, parceque " l'ennemi ne peut ni la traverser, ni l'occuper à son avantage, tant que " cette place est au pouvoir des Autrichiens. Il falloit *faire de Brixen un* " *grand depôt de munitions de guerre et de bouche,* non seulement pour faci- " liter la marche eventuelle d'une armée par le Tirol, mais encore pour " preparer aux habitans armés du pays un point central, d'ou ils auroient pu " tirer les moyens d'arrêter une invasion de l'ennemi, même après la retraite " des armées Autrichiennes, et fermer aux François la communication entre " Munich et Verone."

On the subject of the fortifications of Brixen there have existed a variety of opinions, the great difficulty having been to reconcile the importance and magnitude of the works with the requisite economy. To comply with the proposition of the Archduke Charles, "*faire de Brixen un grand depôt de munitions de guerre et de bouche,*" it was planned to form the ground, from the confluence of the rivers Eisach and Rienz, extending beyond the village of Schabs, into an intrenched camp. This could easily have been done, as the ground is naturally very strong, and it would have commanded the two great roads of the Brenner and the Pusterthal, into the heart of Austria. But it would have had the disadvantage of cramping the energies of the Tyrolese peasantry, who should be encouraged as much as possible, and a fair field provided for their patriotic exertions and peculiar mode of fighting. A plan has, however, been chosen which will comprise all the wished-for advantages.

This has been done by closing the defile of the " Brixen Klause" by a strong fortress called *Franzensveste*, and which is now nearly completed. Preparations are making to fortify the Muhlbach defile in the same manner, near the village of Schabs, at the entrance of the Pusterthal; and plans of a fortress at the village of Klause, a few miles lower down the river, are prepared; but this last work has been abandoned, at least for the present, as unnecessary, and with reason, as the defile itself ought to be impracticable if properly defended, and nowhere could a more favourable field be offered to the Tyrolese for their exertions and prowess, as they would be supported by regular troops in their rear. These *Klausen*, which are numerous throughout the Tyrol, are thus emphatically described. " Il y avoit à la verité, dans quelques gorges, des " ouvrages en maçonnerie nommès vulgairement ' des Cloisons ' (Klausen),

" qui barroient les grands chemins, en s'appuyant contre les rochers, mais de " pareilles barrières ne sont utiles que pour entraver pendant quelque temps " la marche des colonnes ennemis, et leurs transports: elles s'etendent " rarement au-delà des bornes etroites du passage, et ne protegent leurs dé- " fenseurs ni contre le danger d'être tournés ni contre les feux plongeants " des hauteurs dominantes."

This description will hardly be applicable to the village of Klause here alluded to, which forms the southern defile of the intrenched position of *Brixen*, but there is a good specimen of one of these Klausen beyond the village of Schabs, and called the Muhlbach Klause, formerly closing the Pusterthal. It has been the scene of many fierce struggles between the peasantry and columns of the French invading armies, but it is at present unroofed and dismantled. However formidable these may have been considered in former days, it is impossible that regular troops could be detained long by such a desultory warfare, as to all appearance a few shells from howitzers must have the effect of speedily dislodging their defenders.

Franzensveste.—This fort is situated across the entrance of the valley, through which is the great post-road from Verona to Innsbruck, and completely closes it. The fort consists of two distinct works, but as they are connected by a subterranean communication, and are within musket shot of each other, they must be considered as one fortress. The larger or lower fort is built on a granite rock in the centre of the valley, and has in front of it, towards the south, a bend of the river Eisach, which here makes an abrupt turn, and forms a natural ditch 200 feet deep, forcing its way through the rock. The upper fort is on the side of the mountain, and completely commands the lower. The high road passes between them, and it is swept by casemated batteries in every direction.

This may be considered as an almost impregnable fortress, only to be reduced by famine, and consists entirely of casemated batteries and loop-holed walls. It is well furnished with bomb-proof magazines and storehouses for provisions and ammunition, and it is well supplied with a stream of water conducted from a neighbouring height. Should this be cut off, there is still a reservoir in each fort for three months' consumption of the garrison, but no means of collecting rain-water from the surface could be observed.

From its situation this fortress is directly looked into from the mountain

sides, and that at the distance of only a pistol shot; but as the walls are high and loop-holed, this circumstance would be of little advantage to an enemy.

When these forts were commenced, six years since, 8,000 troops were marched to the ground, and immediately began levelling the rock, which was very laborious. Since that time the whole work has been performed by the soldiers, and the regiments have furnished stone-masons, miners, and artificers of every description from their body. During the time they have been so employed they have enjoyed excellent health.

This fortress is now nearly completed (1838), and the only work remaining to be done is levelling the glacis, scarping rocks, &c. The masonry is extremely solid and well built, and the casemates, which are large and airy, are dry and habitable; the arches are all turned in brick.

This fort was popularly reported in Vienna to be one of the first rank, but it was only by a personal visit that its real value could be ascertained. It is calculated for a garrison of 1,200 men, with provisions for three months.

Plate III. *Verona.*—" Il falloit à cet effet être absolument maitre du cours de l'Adige, " et la clef de ce fleuve est Verone dont la position, peut-être sans égale, forme " la base de tout un système sur cette ligne d'operations."

The circumstance of so many actions having been fought in the neighbourhood of Verona will alone point out the great importance of its position as a fortress: Situate on the great road of communication from Italy, through Trente and Brixen to Innsbruck, commanding the road from Milan to Venice, which also leads to Villach and Bruck, it must ever be of the greatest consequence to the Austrians to preserve the lines of the Mincio and the Adige. Should the line of the Mincio, in its front flanked by the fortresses of Pescheira and Mantua, be forced, the *intrenched camp of Verona*, for such it is, offers a point of support where an enemy may be held in check until reinforcements arrive, and all his movements by the valley of the Adige paralysed.

The old fortifications of Verona have been in a great measure adopted for the new works, but with considerable alterations and additions. Those on the right bank of the river, consisting of an old and imperfect trace, having good brick revêtements for the escarp, but without any counterscarp, are changed both in their form and destination. The fronts of fortification are so constructed, that an army or division can with facility make a sortie in force, each column forming in the ditch of its respective front, where a glacis en contre-

ENTRENCHED CAMP AT VERONA.

1 Porta S. Zeno
2 Porta del Palio
3 Porta Nuova
4 Porta del Vescovo
5 [illegible]
6 Ponte delle Pietre
7 [illegible]
8 [illegible]

T. Brenta

Pirona

River Adige

Monte Cagnolino

Redoubts

Redoubt

Castel S. Felice

Castel S. Pietro

Old Walls repaired

Old Bastioned Works re-formed

V E R O N A

To Mantua

To Legnago

Fig. 6
Plan of ground floor of Tower

Section on line A B Fig. 6

Scale for Tower

Sketch

John Weale, Architectural Library, 59, High Holborn

pente allows of their marching out under the protection of the cannon of the ramparts.

The alteration has been effected in the following manner. The bastions, which were small, with retired flanks, are enlarged, and have now detached revêtements, as in Carnôt's system. The faces have been prolonged beyond the line of the flanks, forming orillons, and are covered by a counterscarp not revetted. As the faces of the bastions are very imperfectly seen by the flanks, this defect has in some degree been obviated by block-houses projecting from the salients having two floors and loop-holed. There are three large and solid gateways facing the principal streets, on which cannon can be mounted to sweep the ramparts, but with no other defensive means as redoubts.

That part of the city which is on the left bank of the river is surrounded by very old walls with square and semicircular towers at intervals, without any regular ditch or counterscarp. These are being renewed and repaired, and placed in a state of defence, so as to be secure from insult.

But the neighbourhood of Porta San Giorgio has commanded greater attention, and there more perfect works are constructed. Close to the gate, and adjoining the river, there is a casemated projecting redoubt, and at the distance of 300 and 500 yards respectively are two detached redoubts occupying commanding eminences, the lower having a tower, and the upper a loop-holed block-house in the interior. There are four towers on Monte Cagnolino, the right of the position, and a small redoubt in front of Bastion Santa Toscana.

These, with the exception of the old fort of Castel San Felice, are the chief defences, and together form a permanent intrenched camp or position. There is nothing that is new to remark on the towers and redoubts; they are of stone with brick arches; but, as an opportunity occurred of procuring a plan and section of a tower, a plate is given of it. The towers on Monte Cagnolino have only two floors instead of three, but all have embrasures for cannon and are surrounded by a loop-holed gallery, but without a ditch.

T. K. STAVELEY.

III.—*Notes on Shot Furnaces. By Lieutenant* Nelson, R.E.

The last war was one of cold steel and gunpowder: the changes that have since taken place threaten that the next will be an affair of percussion-locks in the army; and, to a great extent in naval warfare, will be one of red-hot shot and steam vessels. With reference to these alterations, there are few items amongst defensive preparations on shore claiming greater attention than contrivances for heating shot with the greatest rapidity.

A great step has been made, in principle, with regard to these; the old-fashioned Gibraltar grate has been superseded by reverberatory furnaces. I am not aware of the powers possessed by such as have been built at the North Battery, Liverpool, in 1825, and on the Perch Rock, at the same station, in 1830; but by comparing the last (and subjoined) results of the furnace on St. Nicholas' Island, Plymouth Sound, with the Gibraltar report, it will be seen that much remains to be done, as the latter gives one shot in two minutes, and the former does no more, as far as each fire is concerned; although, in this case, there is less danger to be apprehended from sparks flying about.

The experiment made at Plymouth with the temporary chimney points at once to the chief defect. On studying the different documents,—of which sufficient extracts are herewith given,—it struck me that others might be found in the proportions of fire and furnace; and in leaving the building exposed to the rain, so that much of the heat during the first and most precious moments is lost by the evaporating process that is necessarily going on; and which, though admirably adapted to cooling claret,[1] is but an indifferent assistant in heating shot. These "first moments," if not every thing, are nevertheless likely to be invaluable, and not so easily to be retrieved where

[1] This refers not exclusively to the arrangement at St. Nicholas' Island, but to all where the furnace is left unprotected.

an attack by steamers is in question. Considering, also, that the fire might do more work in preparing shot ranged along a much longer furnace, so as to be far advanced in heating by the time their turn comes to be exposed to the fiercer parts of the flame; and being doubtful as to whether the application of a blast would be advisable, I consulted different professional men, by whom the opinions of Sir G. Hoste are well borne out, as well as my own, on the importance of having the whole under cover,[2] and of giving greater length to the body.

To none of the friends who have thus favoured us with their views are we so much indebted as to Sir John Guest, of the Dowlais Iron-works, Merthyr Tydvil; and to his principal agent, Mr. T. Evans, who has spared no trouble on the subject.

The objection of high chimneys being conspicuous, may perhaps be often disposed of, by placing them behind high ground or neighbouring buildings. Provided the access to the battery is easy, a moderate increase to the distance from it would, by the Gibraltar experiments, seem not so very important; as, by that report, a black-red shot may be very effective.[3] With this in view, and with reference to economy in concealment, and in the required protection from moisture, rather a large furnace may be placed in an ordinary cook-house at but an inconsiderable addition to the expense; especially if it be so contrived that the flues may join, though with proper arrangements as to the independent regulation of the draughts. Or, if it be desired to have more than one furnace, they may occupy a building of their own, and be disposed, in plan, as so many radii to a common flue as a central point.

And at worst, where the battery is so open as to have none of the means of cover alluded to above,—so indispensable does height of chimney seem,—the whole furnace might be sunk to a certain depth, and the earth, &c. thus obtained by excavation might be built up as a parapet to complete the screen. This, in a limited sense, may be expensive; but what is ten times the cost of any such, more than a trivial "*fire insurance*" on the value of the arsenal and the magazine of the dock-yard, and shipping therein and in ordinary, to the

[2] Nothing more would be needed than is allowed to every fire-engine in charge of the Barrack Department.

[3] I think it is in "Drinkwater's Siege of Gibraltar" where mention is made of the shot having been brought down to the batteries in wooden wheelbarrows, which were preserved from being burned by the shot being bedded in layers of sand, this last being a bad conductor of heat.

protection of which it contributes so materially? What an evanescent trifle to the outlay on the fortress, laughed at by the train of insulting steamers as they sweep on to the destruction of the above, or of the mercantile town thus sacrificed by inefficiency *perpetrated* in the arrangement of its defences, to effect a saving of the *difference* between the expense of a good furnace and a bad one!

In support of and with regard to much of the preceding, I beg leave to lay before my brother officers,

1. Extracts from the letters of the Commanding Officers of Artillery and Engineers to the Inspector-General of Fortifications, concerning their experiments made at St. Nicholas' Island, Plymouth Sound.

2. Extracts from the letter of the Commanding Engineer to the Inspector-General, respecting the effects of the temporary flue, and other improvements suggested by him.

3. Drawings of the furnace as erected at St. Nicholas' Island, and alterations proposed. (See Plates.)

4. Statement of expenses of ditto, taken from the expense ledger at Devonport.

5. Comments by the Commanding Engineer on the project of Mr. Quick.

6. Ditto on the project of Mr. Coxworthy.

7. Project of Mr. Evans (as communicated and approved of by Sir John Guest), accompanied by extracts from his letters.

8. Experiments with red-hot shot made at Gibraltar in 1771.

No. 1.

Extracts from letters of the Commanding Officers of Artillery and Engineers to the Inspector-General, respecting the shot furnace built at St. Nicholas' Island, Plymouth Sound.

Devonport, 18th August, 1838.

1st Experiment.—Took full $2\frac{1}{4}$ hours to heat the 16 shot immediately over the fire; the hot shot were then removed, and cold shot put in their place, which were nearly $\frac{1}{2}$ hour heating. A foggy morning, and but little wind.

2nd Experiment.—Fire-bars raised $4\frac{1}{2}$ in. nearer the shot; and from $\frac{5}{8}$ in. apart, were opened to $1\frac{1}{2}$ in., so as to allow more air to pass.

The 16 shot immediately over the fire were well heated in an hour. Cold

shot replacing these (after the fire had been lighted 1 hour 40 minutes) were heated in 25 minutes. Others (when lighted 2 hours 25 minutes) were heated in 15 minutes. A very fine day, and a good breeze of air.

3rd Experiment.—An opening was made in the lower part of the furnace door, which might be closed by a slide.

It then took 1½ hour to heat shot; and cold ones replacing them were heated in 20 minutes. We think this opening an improvement. On the whole the furnace may be expected to give shot in from 1½ hour to 1¾ hour from the moment of lighting the fire under most unfavourable circumstances as to wind and weather, and in favourable weather in 1 hour. After the fires have been lighted 2 hours, each fire may be expected to furnish 1 shot every 2 minutes. The furnace acts very well after being thoroughly heated, but it is desirable to heat the first quicker.

Suggested that this may be done by bringing the fire up to 12 inches from the bottom of the shot, it being now 15 inches or 16 inches distant; less fuel would be required, and the draught would be greater. The bars might then also remain at ⅝ inch, as the fuel falls through at 1½ inch apart; the furnace doors will not permit of this being tried just now. On the whole we are of opinion that this furnace is much superior to those now existing in this country, and have little doubt that the shot will be heated quicker with men accustomed to the work.

Devonport, 14th Dec. 1838.

4th Experiment.—The above alterations having been sanctioned, the bars in No. 1 furnace were raised to 10 inches (leaving those of No. 2 at 16 inches) from the grate to the bottom of the shot.

At ¾ of an hour from first lighting, a shot was drawn from each which ignited both powder and shavings. At the expiration of 1 hour shot from No. 2 were red-hot, but those from No. 1 took ¼ of an hour longer. Hence, 10 inches was given up, and 14 inches proposed.

Although the furnace was damp the shot heated quicker than before, which we attribute to wood having been used for the first 20 minutes; and afterwards, wood and coal mixed. When once thoroughly heated, coal alone may be used.

Devonport, 14th Feb. 1839.

Referring to the above,

5th Experiment.—Bars in No. 1 raised to 14 inches from bottom of shot. No. 2 left at 16 inches. In 1 hour No. 2 gave a red shot, and No. 1 in $1\frac{3}{4}$ hour. Wind east, and favourable to No. 2.

6th Experiment.—Bars as in Experiment 5; wood alone used for 1 hour 20 minutes; then wood and coal. In 1 hour 23 minutes No. 2 gave a red shot, and No. 1 in $1\frac{1}{2}$ hour. Wind west, and favourable to No. 1. Much rain prior to experiment; furnace very damp; and fires long in getting up.

7th Experiment.—Bars as in Experiment 5 as to distance from shot; but one bar was returned to each grate to reduce the $1\frac{1}{2}$ inch distance. Wood only used for the first 1 hour 17 minutes, and then entirely coal. In 1 hour a shot from No. 1 was black red; No. 2 not. In $1\frac{1}{4}$ hour No. 1 was bright red; No. 2 black red. Wind south, equally favourable to both; day very clear; fires burned well.

This was decidedly in favour of 14 inches.

Conclude hence that 16 inches or 14 inches is immaterial; but when wood and coal can be procured, 14 inches; when wood only, 16 inches. Also, that the state of the weather has more to do with it than a slight difference in these distances.

Have not been able to regulate the kind of fuel by the state of the weather; but, once a clear bright fire is raised, the sooner coal is used the better.

Are of opinion that, on very favourable days, with *dry material,* shot may be obtained in 1 hour or $1\frac{1}{4}$ hour, but under ordinary circumstances from $1\frac{1}{2}$ hour to $1\frac{3}{4}$ hour.

No. 2.

Devonport, 9th April, 1839.

In a letter to the Inspector-General of Fortifications, the Commanding Engineer remarks that the great defect of the furnace at St. Nicholas' Island is the want of draught. He had therefore a wooden flue built giving an additional 15 feet of height; this increased the draught materially. In $\frac{1}{2}$ hour from lighting, a shot ignited powder and shavings *immediately.* In 45 minutes shot became black red; in 50 minutes bright red. Is of opinion that the furnace is capable of still greater improvement; therefore proposes

1st. To raise a flue 30 to 50 feet high.[4]

2nd. To raise the ash pit about 18 inches higher than Captain Melhuish's, and also to sink it 6 inches below the ground, so as to form a pit to be filled with water, the steam from which is said to increase the draught.

3rd. To have openings all round the ash pit, with valves to close, and so avail oneself of any wind.

4th. To decrease the size of the furnace by cutting off the superfluous spaces at the two ends where the shot are put in and taken out, by altering the ends from straight lines to curves, and by lowering the end of the arch as it recedes from the fire place.

5th. To contract the upper part of the fire place through which the flame passes over the shot. The alteration of the part where the shot is taken out entails the necessity of one in the ends of the bearers, and a moveable wrought iron grating to be substituted for the ends of the bearers thus cut off.

As the height of the chimney may be considered to be objectionable, proposes to lead it up the glacis behind; also to build a single one on this principle at Plymouth Citadel. Encloses an estimate

For a single furnace	£ 58	11	$0\frac{3}{4}$
For a double furnace	117	10	6
Actual expense of the furnace at St. Nicholas' Island	62	13	9

[4] The proprietor of some very extensive iron works with whom I have corresponded says, "To obtain a very sharp draught, the chimney should be 20 inches square in the interior, and perhaps 25 to 30 feet high." The same gentleman agrees with Sir G. Hoste as to the propriety of the change suggested in the position of the doors.

No. 4.

Specification and actual expense of building the furnace at St. Nicholas' Island.

Item	cwts.	qrs.	lbs.	Rate				£.	s.	d.
Excavating 8 cube yards of ground for foundations								0	4	0
237¼ cube feet rubble masonry in footings to walls, under the runners and over arches.—13⅓ superficial feet 4″ limestone coping weathered, throated and set in mortar.—2 flue holes, 9″, cut in ditto.—Letting in standards for dampers, and running with lead.—Removing iron work from stove to furnace.—2⅙ cube feet of granite set.—6 feet 11 inches superficial plain work on ditto.—2 feet 9 inches sunk work on ditto								7	2	5
209½ feet red[d]. brick work in walls, gables, chimneys, ash pits, and bases to granite cap-stones.—150½ cube feet fire brick in Stourbridge loam, including fixing iron work, cuttings, splays, flues, &c.—6½ superficial yards brick on edge in bottoms of ash pits, and under slating								25	2	9¼
Lime in concrete foundations, 30*s*.—Carpenter's work in centering, &c., 22*s*. 6¼*d*.								2	12	6¼
10 cast iron runners, weighing	14	1	15							
28 ditto fire bars; 6 ditto bearing ditto ,,	8	2	1							
2 ditto dampers; 6 ditto doors & frames ,,	10	1	0							
Cast iron	33	0	16	at 9*s*. 4*d*. per cwt.	15	9	4			
6 sets wrought iron hooks and rides, latches, catches, and straps for fixing frames, including fixing and fitting	3	2	11¾	at 32*s*. 10*d*. per cwt.	6	5	11	25	14	11
Moulds for castings					1	10	0			
Miscellaneous, *e. g.* chains to dampers, &c. &c &c.					2	9	8			
Slater								1	17	1½
Total								£62	13	9

No. 5.

Projects by Mr. Quick and Mr. Coxworthy.

Mr. Quick, a baker at Stonehouse, informed Sir G. Hoste that he could heat a 32-pounder shot in his oven in 10 minutes. One was sent, and Sir G. Hoste, Captain Wortham, and the Clerk of Works, were in attendance, as appointed. On their arrival, Mr. Quick said that the shot was *then* in the oven. There was a very fierce fire, and the shot was in the hottest part of it, yet it took $\frac{1}{4}$ hour to heat it. However, the furnace was well contrived, and the flue, according to the proprietor, is 60 feet high.

Shortly afterwards Mr. Quick forwarded a project for a shot furnace, which was sent to the Commanding Engineer by the Inspector-General of Fortifications for report;—this was given to the following effect:

The Commanding Engineer disapproves of it as expensive and complicated, very difficult to use, and would not heat as quickly as that at St. Nicholas' Island; what good points it possesses have been already suggested by himself. See preceding letter of April 9, 1839.

1st. In Mr. Quick's furnace, the shot farthest from the fire must be drawn first.

2nd. By experiments made here, a shot will not roll along the slope proposed; it will require some very long instrument to push or pull them.

3rd. If the floor be sloped, to enable them to run, they would jam at the door, as proved during the experiments here.

4th. Having once opened the damper, the shot would prevent its closing again.

5th. The expense would be more than thrice that of Captain Melhuish's furnace, Mr. Quick himself estimating it at £200.

6th. Captain Melhuish's furnace heats 80 instead of 16 shot, as supposed by Mr. Quick.

No. 6.

Mr. Coxworthy, one of the clerks employed in the office of the Inspector-General of Fortifications, having also sent in a project on the principle of a crucible furnace, it was likewise forwarded to the Commanding Engineer for report;—which was given as follows:

1st. The bars have not sufficient slope; give what slope you will, they are always liable to roll and jam; hence any project should admit of reaching the shot so as to move them forward.

2nd. Taking out shot and putting in fuel from the top will be inconvenient; there must be a drawing-door; and when this is done, the furnace resembles that at St. Nicholas' Island, except that there the fuel is introduced by the side, and clear of the shot, which is preferable.

3rd. Mr. Coxworthy's plan will not give *clean* shot, which is important, though it may *perhaps* give them quicker. When kept separate from the fuel, the blaze of a coal fire and a good *draught* would probably be better than coke with a *blast*.

4th. Agrees with Mr. Coxworthy in a flue being indispensable.

5th. Mr. Coxworthy's being a crucible furnace, has a different object from a shot furnace, its purpose being rather to give the most intense heat, whilst we want a *certain* heat only in the shortest time from lighting the fire.

No. 7.

Plate VI. *Extracts from the letters of Mr. T. Evans, accompanying his drawings of a furnace capable of heating about* 100 *32-pounder shot.*

" If you have work enough for two fires[5] of the dimensions sent, you will find a saving in making one furnace large enough to do the duty of both: if not, you can vary the width to such size as may be required.

" By all means keep the furnace under cover; it will last longer, and save much fuel.

" No blowing apparatus will be required for this plan: in case the furnace should not heat quickly enough, raise the stack a few feet."

With regard to the furnace at St. Nicholas' Island, and the alterations suggested by the Commanding Engineer, Mr. Evans observes:

" I consider both defective in the grate, which must always be the case if the balls are to be drawn out over the fire; because, to do this, they must be supported by some grating or other cast iron work, which must always either burn down quickly if the furnace is properly heated, or else prevent the fire from burning.

[5] See furnace at St. Nicholas' Island.

"There must be a stop (such as the edge of the plate *c*) to keep the shot in the position they stand on, until they are hot enough; then a hook must be introduced into the furnace, and inserted at the back of, or under, whichever ball (1, 2, 3, 4, 5, or 6) you intend to move; turn it over on the plate *c*, and it will roll, and another will take its place: the whole furnace could be discharged in half a minute in this way. Should it be found more convenient to have the discharge-door free, put a small door (*i*) behind, through which the hook may be passed for turning over the shot from the bearers to the inclined plane *c*."

(Signed) T. EVANS.

N. B. With reference to the iron work at the back, through which the shot are placed on the bearers, it is the only part of the drawing which is not quite clear; though this, as it happens, is perhaps unimportant, as no fault was found during our experiments with the somewhat simpler arrangement corresponding in the furnace built at St. Nicholas' Island.

No. 8.

Experiments with red-hot shot.

(Taken from the Records in the Proof Square, Woolwich Arsenal.)

Gibraltar, March 13, 1771.

The following experiments were made with red-hot shot heated in a newly invented furnace at a common smith's forge. The frame was made to contain 14 24-pounder shot, and, in 55 minutes from lighting the fire, the shot were red hot; they were replaced with cold shot, which likewise became red hot, but in 28 minutes; consequently that arrangement will produce 14 shot in the first hour, and one every two minutes as long as may be required.

A shot thus heated and then laid on the ground in the open air fired powder almost instantaneously, at the end of ½ hour; at the end of 40 minutes, in 3 seconds; 60 minutes, in 10 seconds; 70 minutes, in 13 seconds; in 75 minutes it only changed colour, but did not go off. It was likewise found that dipping a ball two or three times in cold water had no perceptible effect in cooling it.

A shot was enclosed in a 12-inch cube of fir timber; it soon began to blaze, and in 6 hours was entirely destroyed.

A shot was laid in cold water for 1 minute, and after this it was laid on the ground as before for 30 minutes. It fired powder after 35 minutes, in 2 seconds; 40 minutes, in 3½ seconds; 47 minutes, in 4½ seconds; after 60 minutes it did not ignite.

A shot was then laid in cold water for 1½ minute; the instant it was taken out, powder was dropped upon it, but it was 13 seconds[6] in going off; after 1 minute, in 4 seconds;[6] 1½ minute, in 3½ seconds; 2 minutes, in 3 seconds; 3 minutes, in 2½ seconds; 4 minutes, in 2 seconds; 6 minutes, in 4 seconds; 8 minutes, in 5 seconds. After 2 minutes' immersion a shot would not fire powder.

When laid on the ground as before for 4 minutes, and thrice dipped in water, it was thrown amongst cordage, &c. In 7 minutes the flame became very considerable; an engine was then played for 2 minutes on it, notwithstanding which it blazed again in 50 minutes.

A 32-pounder shot, in open air 4 minutes, and thrice dipped, was enclosed, as above, in a 12-inch cube of oak, quite green. It began to smoke immediately; in about 4 hours the fire became considerable, but it did not blaze; in 8 hours the wood fell in pieces; in 12 hours it was entirely reduced to ashes; and 21 hours after taking the shot from the fire it was too hot to bear one's hand upon for any time.

R. J. Nelson,
Lieutenant Royal Engineers.

Devonport, Feb. 1840.

[6] To what is this and other anomalies in this series to be attributed? Could the 13 seconds have been occasioned by any steam flying off at "the instant it was taken out?"

SHOT FURNACE AS ERECTED AT S^T NICHOLAS ISLAND PLYMOUTH SOUND

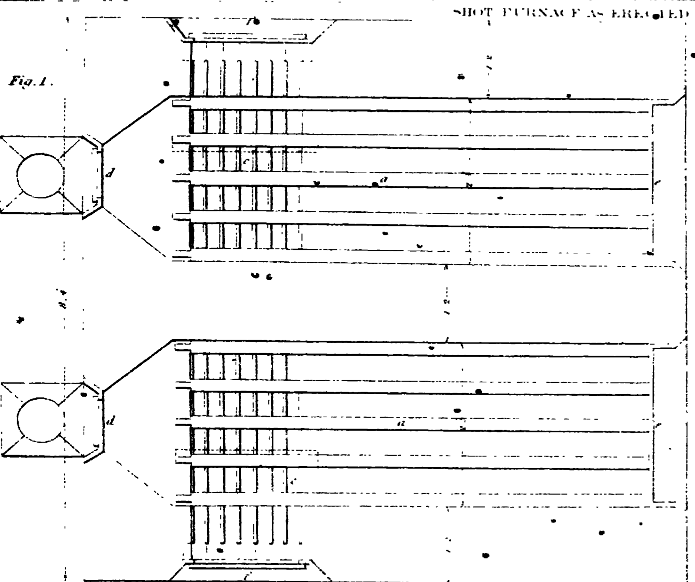
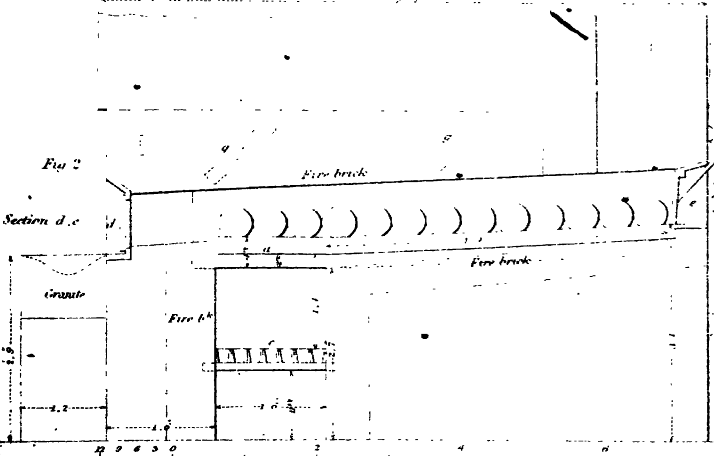


Fig. A



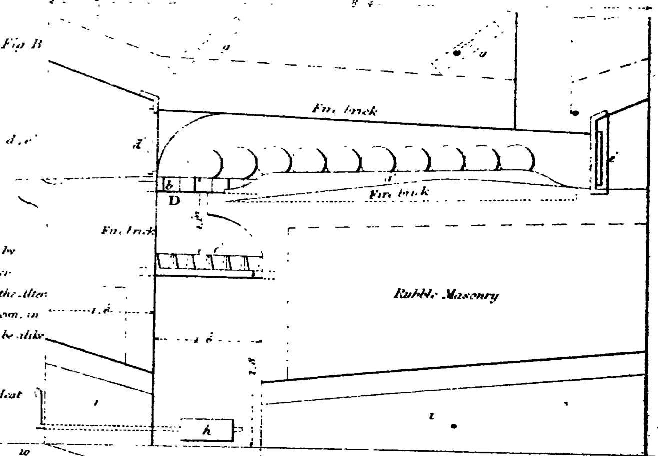


Fig. A & B shew Alterations Suggested by The Command^g Engineer

N.B. In these lower Figures the Alterations proposed only are shewn, in other respects the Furnaces to be alike.

All parts Exposed to the Heat line with fire brick.

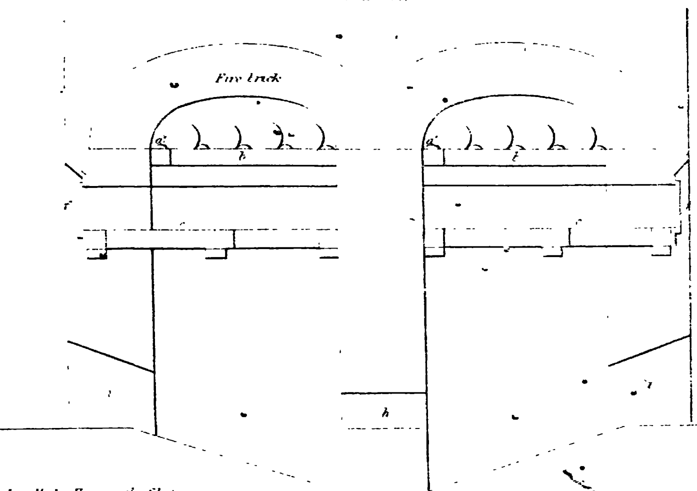
12 9 6 3 0 2 4 6 8 10 Feet

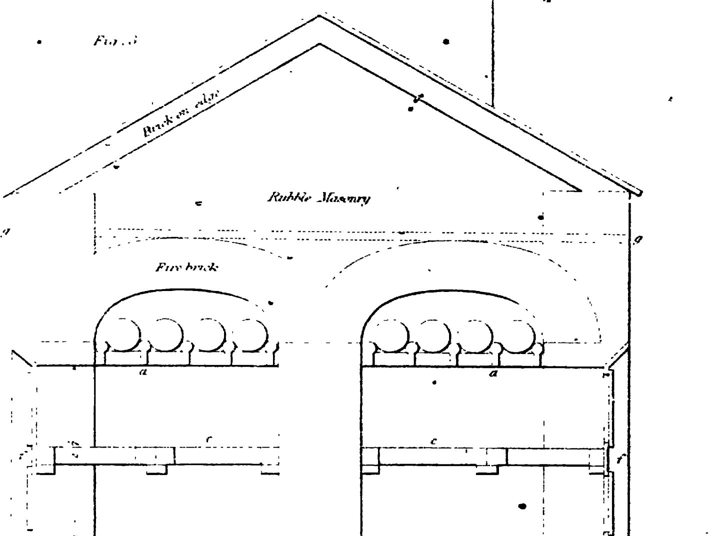
John Weale, Architectural Library 59 High Holborn

W. A. Beever

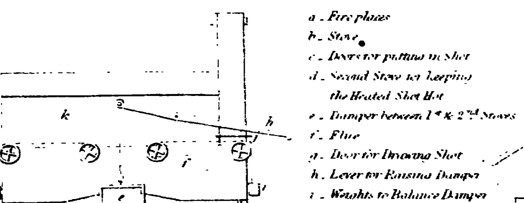
FURNACE AT S^T NICHOLAS ISLAND.

D^O IMPROVED.



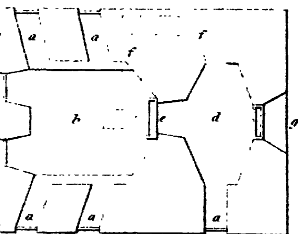


In all the Figures, the Shot are put in at e or e' Taken out at d or d'. Fuel is Introduced at f or f'.



a. Fire places
b. Stove
c. Doors for putting in Shot
d. Second Stove for keeping the Heated Shot Hot
e. Damper between 1^st & 2^nd Stoves
f. Flue
g. Door for Drawing Shot
h. Lever for Raising Damper
i. Weights to Balance Damper
j. Damper to fire places
k. Archway to fire damper
l. Iron Doors to Archway
m. Hole in Door for Lever

"The Bottom of the Stove to have a Slope of 1^in to 1^ft & 1½^in to 1 F^t at the Damper so that the Shot may Run freely."



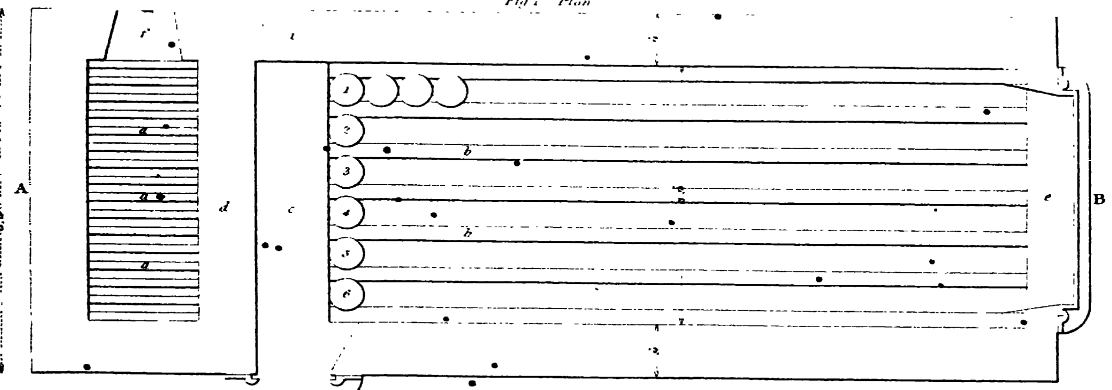
Scale 8 F^t to 1 Inch.

12 9 6 3 0 4 6 8 10 Feet

John Weale Architectural Library, 59 High Holborn.

W. A. Beever

FURNACE PROPOSED BY MR T. EVANS



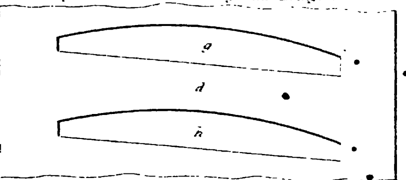


Fig. 4 Section at E F. through the Bridge d

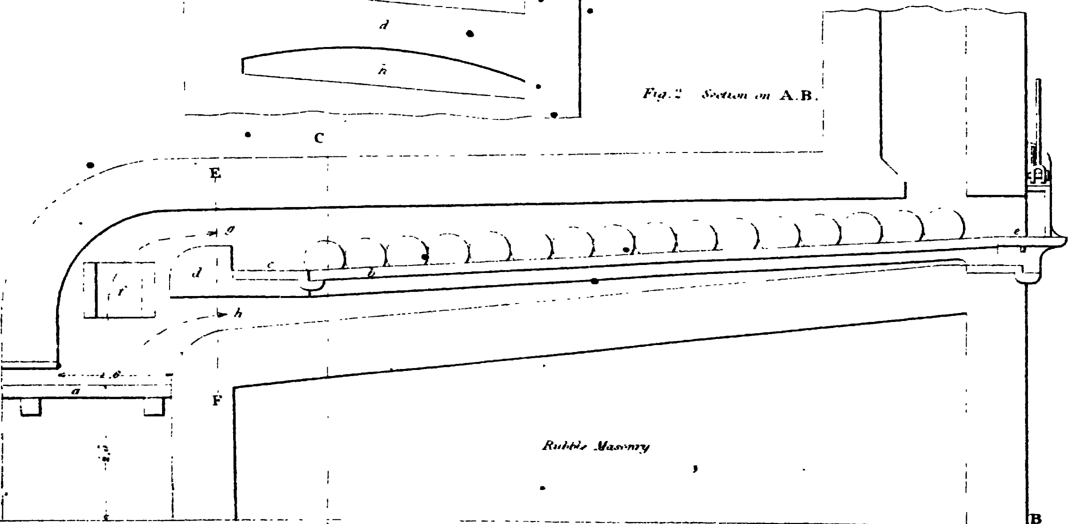


Fig. 2 Section on A.B.

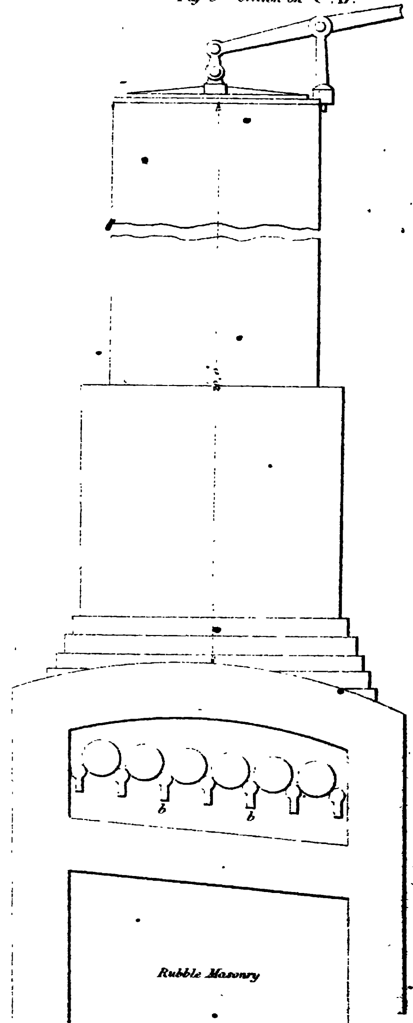


Fig. 3 Section on C.D.

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IV.—*A description of a New Steam Apparatus for Drying Gunpowder, recently set up in the Royal Laboratory at Woolwich, as proposed by Lieut.* CAFFIN, *of the Royal Artillery.*

THE boiler (C), which is of wrought iron, and holds about 150 gallons, is furnished with man-hole, stop cocks, steam pipes, safety valve, steam water and mercurial gauges, in the usual manner; the safety valve is regulated to work at a pressure not exceeding 14 lbs. to the square inch, and at this pressure the temperature of the stove is about 155°. Plate VII. fig 1.

The boiler is set up in a room 10 feet from the building which contains the drying apparatus.

The steam pipe (A), which communicates with the boiler and the upper part of the cast iron cylinders (L), is enclosed between the buildings, in a square wooden trunk filled with charcoal dust to prevent the loss of heat; another pipe of communication (B) connects the lower part of the apparatus with the boiler, and which is protected and enclosed in the same way as the former; the use of this pipe is to return back the condensed water from the apparatus, by which arrangement much fuel and expense and trouble are saved.

The drying apparatus consists of nine cast iron cylinders (L), connected at top and bottom by cross pipes of communication. Each cylinder is surrounded by a large wrought iron case (Q), and the space between the case and the cylinder is filled with eight smaller wrought iron cases (M), open at both ends, and of the same length as the cast iron cylinders. For the dimensions of the different parts of the apparatus in general, see the drawing.

The whole of the steam apparatus is enclosed in brick casing, having sliding air holes or ventilators (P) at the bottom part, to admit air on either side at pleasure. On the top of this brick casing is placed the drying frame or tray (O). This drying frame or tray lifts off, and has a copper-wire bottom (eight mashes to the inch), over which is a fine wove hair cloth; and underneath the Plate VII figs. 1, 2, and 3

wire, bars of wood, about $1\frac{1}{2}$ inch apart, are placed, to support the wire work when loaded with powder. Under the frame or tray a canvass cloth (N) is suspended by hooks driven into the framed coping of the brick casing, to receive any dust of the powder which may fall through the horse-hair cloth.

The powder is spread on the horse-hair of the frame or tray, about three barrels at a time, and which covers it about $2\frac{1}{2}$ inches thick; it is spread equally over the surface by means of a wooden rake covered with leather.

The fire under the boiler being lighted, and the steam raised to the pressure of 6 or 7 lbs. on the square inch, the steam cock is to be opened, and the steam having been admitted into the cast iron cylinders a few seconds, the air cock (F) is to be opened for the purpose of allowing the cold air that has collected in the cylinders to escape; after which it is to be turned off, and the condensing cock (B) turned on, which allows the condensed steam to return to the boiler, when the cast iron cylinders will very shortly become heated to the boiling point of water (212°); the ventilators at the bottom are opened to admit air from without, which will pass in a quick current up and through the small wrought iron cases surrounding the cylinders, and from these iron cases being in close contact with the cylinders, they become heated to a certain degree, and consequently greatly increase the surface of heated metal. The current of air passing through these cases becomes heated and highly rarified, and in this state passes quickly through the gunpowder, it having no other means of escape, and thus the temperature of the whole of the powder becomes gradually raised; it is frequently turned over with the rake, so as to bring every grain in contact with the heated current of air. In between two and three hours the temperature of the whole of the powder will be about 145° Fahrenheit: there is no doubt that the temperature on the frame or tray would rise to 200°; but for the purpose this apparatus is intended, 145° or 155° is fully sufficient.

The advantage which this new mode of drying gunpowder possesses over the former mode appears to be,—First, economy in the original cost of building and apparatus for conveying and applying the steam heat, as well as in fuel and time in carrying on the work. Secondly, the more complete and perfect drying of the powder: the current of heated air passing through the mass of powder and between every grain causes quick evaporation of all moisture; and it has been found, upon trial of powder just newly made and dried by the old steam stove, and immediately after placed under this new process, that no less

than 10 ounces in one barrel of 90 ℔s. more of moisture were expelled; and as the average of moisture in 90 ℔s. of gunpowder, as it comes from the corning-house, and before it has been stove dried, is about 40 ounces, it would appear that the old process does not evaporate more than three-fourths of the moisture contained in the powder; and it is believed a doubt cannot exist as to the necessity of gunpowder being kept perfectly dry, and when once so, of the much less liability of its afterwards so soon attracting moisture.

The whole of this apparatus is conveniently fitted up in a small building about 12 feet square, and is perfectly safe from danger or accident.

300 ℔s. of old deteriorated gunpowder has also been placed under this process, and after having been submitted to the heat for about 2½ hours, it was found, upon re-weighing the powder, that 4½ ℔s. of moisture had been expelled, and the grain had become as firm and dry as when first made.

W. G. C. CAFFIN,
Lieutenant Royal Artillery.

Fig. 1 represents the boiler and its appendages. Plate VII.

AA, &c. The pipe conveying the steam from the boiler into the cast iron cylinders from which the heat is produced.

BB. The condensing pipe through which the condensed steam is returned to the boiler.

C. The boiler.

D. The man-hole for the purpose of cleaning the boiler.

E. The safety valve.

F. A pipe attached to the condensing pipe, through which cold air collected in the cylinders (between the workings) is discharged.

G. The pipe communicating with the boiler, which contains at the elbow (H) quicksilver; the steam acting upon this forces it up the pipe, and shows by the plummet (I) on the index the number of ℔s. weight pressure of steam on every square inch of the boiler.

J. The damper.

K. The water gauge for showing the height of water contained in the boiler.

Figs. 2 and 3 exhibit a plan and section of the drying apparatus.

LLL. Cast iron cylinders through which the steam passes from the pipe (A) into the condensing pipe, and from thence it is returned into the boiler.

MM, &c. Sheet iron cases surrounding the cast iron cylinders for circulating the hot air.

N. A sheet or covering cloth, which is hung on hooks to the framework between the tray and the cylinders, for collecting the dust that may fall through the drying sieve.

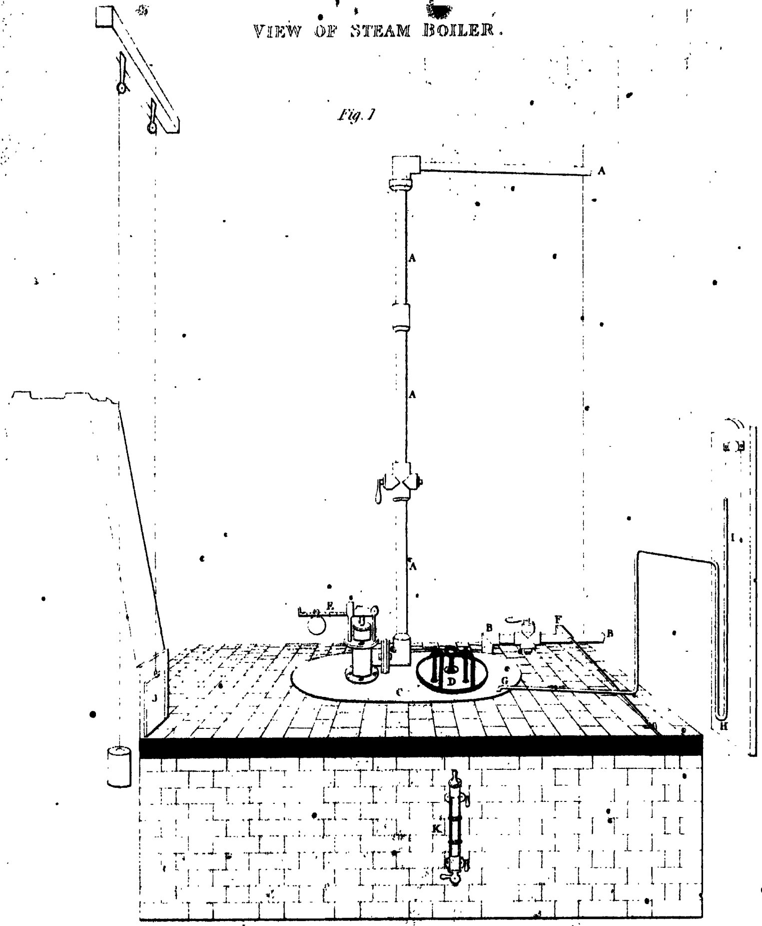
O. The frame or tray covered with horse-hair cloth, upon which powder or other articles are laid for drying.

PPP. The ventilators for admitting a current of fresh air to the heating apparatus, by which means the hot air is forced through the tray and powder, &c.

QQ. The sheet iron cases which surround the small ones marked (M).

VIEW OF STEAM BOILER.

Fig. 1

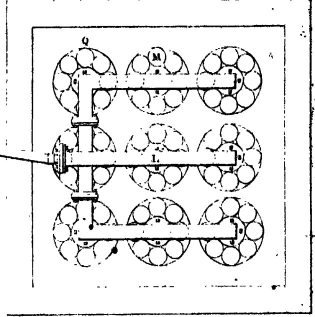


Section of drying Room, and Plan of Steam Pipes, and Cylinders for containing hot Air

Fig. 2

O
N
A
R
S
M M M M M M
L L L
B
P P P

Fig. 3



R S *In Fig 2 is the Section through the same in the Plan Fig. 3*

Scale 6/10 of an Inch to a Foot

New Steam Apparatus for drying Gunpowder as proposed by Lieutenant [illegible] Royal Artillery

V.—*Memoranda on Blasting Rock. By Maj.-Gen. Sir* J. F. Burgoyne, K.C.B.

The prevailing mode in practice for blasting rock is very injudicious in many particulars.

Though a matter of extensive application, and of much importance in engineering works, in quarrying, and in mines, it does not appear that any systematic attempts have ever been made for its improvement.

The great difficulty of judging precisely of the causes of relative effects in blasting rock has given rise to the adoption of many principles that there is reason to believe are founded on fallacies.

The points adverted to in the following memoranda are worthy of attention, and some of them, of further elucidation. Very many of the statements contain matter so thoroughly known and well understood, that it may be considered superfluous to have introduced them, but it is difficult to draw the line between what may be old and what new to the reader, and much was introduced in order to carry through the reasoning and to make it intelligible.

GENERAL PRINCIPLES.

Two leading errors are committed by quarrymen or miners, in general.

One is, by very commonly selecting an injudicious position for the charge, by which the action of the powder is exerted in the direction of the opening where it was introduced; and the other is, the adopting as a rule for the several charges, to fill a certain number of feet or inches of the hole bored, usually one-third of its depth, instead of employing given weights adapted to the *lines of least resistance.*

The *line of least resistance* is that line by which the explosion of the powder will find the least opposition to its vent in the air. This need not necessarily

be the shortest line to the surface; as, for instance, a long line in earth may, from the same charge, afford less resistance than a shorter line in rock.

Supposing the matter in which the explosion is to take place to be of uniform consistence in every direction, charges of powder to produce similar proportionate results ought to be as the cubes of the lines of least resistance, and not according to any fanciful depth of hole bored.

Thus, if 4 ounces of powder would have a given effect upon a solid piece of rock of 2 feet thick to the surface, it ought to require 13½ ounces to produce the same effect upon a piece of similar rock 3 feet thick; that is,

	Cube of 2 feet line of least resistance.		Charge of powder in ounces.		Cube of 3 feet line of least resistance.		Charge in ounces.
as	8	is to	4	so is	27	to	13½

or, what is the same thing, half the cube of the line of least resistance expressed in feet, will, on this ***particular datum***, be the charge in ounces, as follows:

Lines of least resistance in feet.	Charge of powder. lbs.	oz.
1	0	0½[1]
2	0	4
3	0	13½
4	2	0
5	3	14½
6	6	12
7	10	11½
8	16	0

These quantities being of common Merchants' blasting powder, will be found adequate for any rock of ordinary tenacity; but a precise datum should be ascertained by a few actual experiments on the particular rock to be worked.[2]

[1] To so small a quantity as ½ ounce a little excess might be added, but ¼ ounce, or ½ ounce more, will be sufficient.

[2] In the granite quarries of Kingstown (near Dublin) these charges were sufficient to open the rock where there were no fissures, apparent weakness, or other advantage; but where the line of least resistance was not that of the hole bored, the effect was either to bring it down, or only to crack it, according to the quality of the powder used.

Thus, with a 2-feet line of least resistance, (A to B, fig. 1,) whether 4 ounces, or 6 ounces, or 8 ounces, are requisite to produce a good effect; with 3-feet line of least resistance, whether 13½ ounces, or 18 ounces, or 27 ounces, &c.

Fig. 1.—(Section.)



And subsequently, as occasions may offer, with greater lines and larger charges; for it may be found in practice, with regard to some species of rock, that with larger charges, slighter proportionate shocks, and consequently less powder, may produce adequate effect. On the results of these trials a scale may be adopted for the regulation and guide in the subsequent service.

With regard to the first error above mentioned, that of leaving the action of the powder to be exerted in the direction of the hole bored, one consequence is, that with small charges, commonly a part of the explosion finds comparatively easy vent by that opening, (in spite of the best tamping,) and is wasted; and it is only the excess that acts in producing the effect required on the rock; whereas, if the explosion were forced through another direction, the whole of its power would be exerted beneficially. But the great objection is, that the rock is then so much more firmly bound all round the charge, as to oppose and lessen in a very great degree the extension of the effect of the explosion.

It must be understood, that even although the line of least resistance should be in the direction of the hole bored, the *depth of the hole* will by no means be the measure by which the proportions of powder for the charge can be taken according to the above rule, namely, as the cubes of the lines of least resistance.

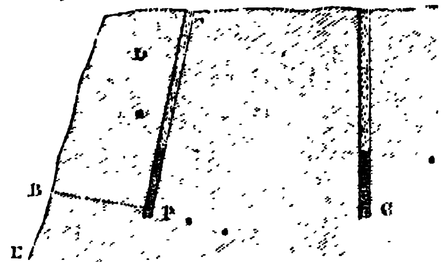
1st, because the tamping, however good, or by whatever contrivance strengthened, cannot be equal in strength to the solid rock.

2ndly and chiefly, because of the various proportions of the entire depth of the hole occupied by different charges of powder: thus, ½ ounce of powder will occupy an insignificant proportion of the depth of even 1 foot of a 1-inch hole, and also the 4 ounces for a 2-feet line of least resistance would fill only 2 inches of a 1-inch hole, and consequently occupy one-twelfth of the 2 feet, and leave 1 foot 10 inches of tamping; while the 13½ ounces for a 3-feet line of least resistance would occupy of a 1-inch hole above 6 inches, that is, more than one-sixth, and leave only 2 feet 6 inches of tamping, and consequently of resistance, such as it is.

This might be remedied in one way, by applying holes of larger diameters for increasing charges, but, by so doing, an increased amount of the less resisting medium (the tamping) would be the consequence, which again renders the calculation, founded on a resistance of solid rock, incorrect.

There is another reason why the powder is ill applied when the explosion takes place in the same line as the bore, which is, that it is placed longitudinally with the line of least resistance, as at C, in fig. 2, and not perpendicular to it, as at P; when much extended, the elongated form in either is bad, but it is worst in the former case.

Fig. 2.—(Section.)



When the common mode of blasting is adopted, a loud report is heard like a gun, (louder in general in proportion to the less *useful* effect produced,) and fragments of stone are frequently thrown to a considerable distance; but when done judiciously, the report will be trifling, and the mass will be seen to be lifted, and thoroughly fractured, rent, or thrown over, without being forcibly projected.

It is the irregularity and extent of the violent explosion following the ordinary process, that renders it so peculiarly difficult to form an accurate judgment on the proper charges for each circumstance; the consequence is a practice purely empirical. The miner or quarryman will give as his rule either a proportionate depth of hole, or, aware how frequently that must prove erroneous, is driven to his usual answer, that he knows from the *appearance* of the situation what to apply; that is, in fact, admitting that it is a matter of caprice, and provided a certain effect is produced, he is little aware how much time, powder, and labour, may have been wasted.

It is difficult to make ordinary quarrymen, or even overseers, understand correctly the meaning of the lines of least resistance: after appearing to comprehend it, they are frequently observed to confound it with the length of hole bored, or with some conceived necessary direction either vertical or horizontal.

With respect to the second error mentioned, it can easily be shown how very erroneous *must* be the rule of measuring the charge by any given proportion of the depth of the hole, since the quantity of powder will in that case depend, not only on the depth, but also on its *diameter*, with which it can have

no relation: thus if a six-feet hole is to be bored, it may be an act of chance or caprice whether a jumper of 1½-inch gauge, or of 2 inches, or of 2½, were used; whereas the third of the depth, or any given number of inches of the 2-inch, would hold very nearly *double* the quantity of powder that would be contained in the 1½-inch; and of the 2½-inch, one half more than in the 2, and nearly *three times* as much as in the 1½.

Such a rule also takes no account of the quality of the rock, which in reality will cause the greatest difference in the effect; a given depth of hole being applied to hard or soft rock indiscriminately.

Although some allowances may be made in extreme cases, yet it will be found in most books and papers on blasting rock, that a *usual* charge is one-third of the depth of the hole; and the same will be found to be the actual prevalent practice.

As to the experience by which it might be assumed, that the miners will modify this rule, and regulate the proper charges to give in each case, the value of such practice, unaided by better *principles*, must be small, where the results are so indistinct. A loud explosion takes place, and the rock is more or less separated, but no proof whatever is afforded that the charge has been precisely, or even nearly, what it should have been; and being regulated by no rule, (for in this case of leaving it to the miner's judgment, the only rule is abandoned,) the experience, to be valuable, should be of precisely similar cases, whereas in blasting they are constantly varying, in size and depth of hole, and in many other circumstances. If the rock were uniform, and the application of the charge always in similar holes and situations, a tolerable rule of thumb experience might perhaps be obtained; but it is quite otherwise, and among the circumstances that must tend to perplex an ordinary miner workman, would be, that the true principle for charges is, as the *cubes* of the thickness of the resisting medium, but which he would certainly regulate by a much more gradual proportionate increase, such as, doubling, trebling, or squaring at most.

In order to quarry with good effect for saving labour and powder, an exposed front, either vertical or horizontal, should, if possible, be established on the rock on which to operate; principally to obtain a line of least resistance in a different direction from that of the hole bored.

Thus if a charge of powder were placed at P, fig. 2, with a line of least resistance to B, the explosion would force its way through at B, shatter and loosen the whole mass at D, and make cracks to a great extent towards E;

whereas if the hole had been bored direct from B to P, or as at C, (as is usually practised by common quarrymen,) the resistance being excessive in every direction, except in the direct line of the hole bored, it may be easily conceived that the same charge would produce far less effect.

Or to adopt a more practical illustration, suppose ledges of rock require to be cleared away to a certain level for a road, navigation, or other object; instead of boring holes + + +, the effect would be far better by inclined holes A, B, C, fig. 3, applied in succession after the above-mentioned principle.

Fig. 3.—(Section.)

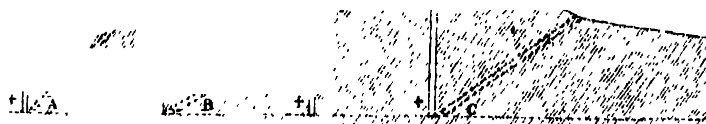


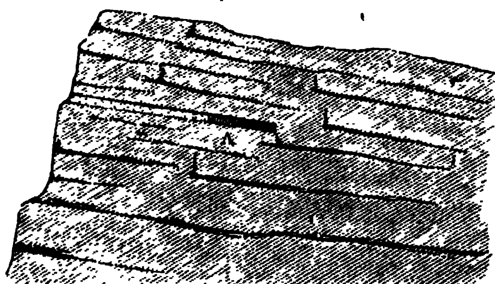
Fig. 4.—(Section.)



Where there is a high face of rock, a system of undermining may be advantageously employed: thus a blast at A, fig. 4, would make an opening easy from C to D, and the mass E, if not shaken, which it probably would be, so as to be worked on with crowbars and wedges, would be brought down by very slight subsequent blasts.

When the rock is stratified, and in close parallel beds and seams, the holes should be bored in the direction of the joints, and the powder laid along them as at A, fig. 5, which will have much more effect in lifting large masses than if placed across the grain, and the operation of boring will be easier.

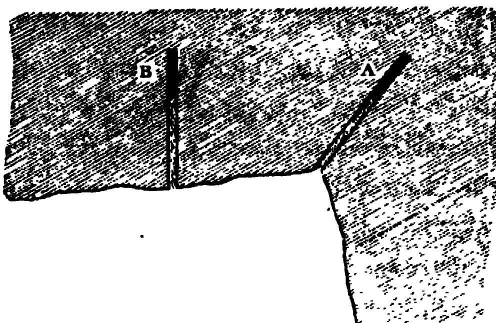
Fig. 5.—(Section.)



The worst situation for a charge of powder is in a re-entering angle, as at

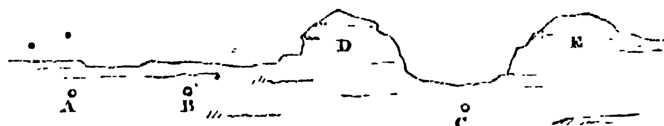
A, fig. 6: the rock exerts such pressure all around it, that very little effect can be expected; nor is the position much improved at B.

Fig. 6.—(Horizontal Section.)



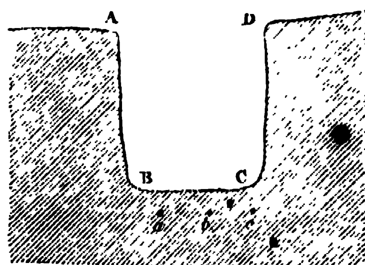
This situation of a re-entering angle occurs very frequently, and should be avoided as much as possible. Thus a charge may be lodged in a hole C, fig. 7, having the same length of line of least resistance as at other holes, A or B; but the effect of the explosion will be greatly reduced by the masses D, E.

Fig 7.—(Plan.)



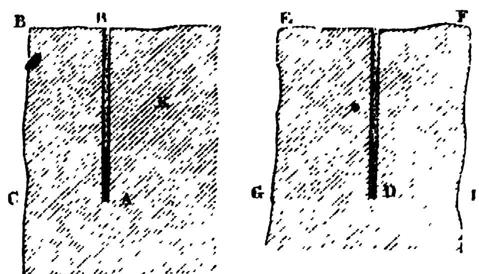
An important illustration of this disadvantageous position for the charge will be experienced in cutting through any narrow confined space A, B, C, D, fig. 8, either horizontally, as in the first drift, or opening, all through a tunnel, or vertically, as in sinking a shaft: blasts at *a*, *b*, or *c*, must be extremely ineffective.

Fig. 8.—(Section.)



A projection, on the contrary, is the most favourable situation to produce the greatest effect with the smallest means: a given quantity of powder, for instance, at A, fig. 9, would remove the mass B, B, A, C, and make partial cracks on the side K, but the same quantity at D would remove E, F, G, H, or nearly double the mass.[3]

Fig. 9.—(Sections.)



Cases, however, frequently occur requiring a deviation from what, under

[3] It will not have quite this effect, as the greater resistance on the side K, in the one case, will increase the effect towards C; but that circumstance does not affect the general consideration of the principle here adverted to.

ordinary circumstances, would be the most favourable application of the charge, either owing to the quality of the rock, or where other objects are of more importance than the consumption of powder, or of labour in boring.

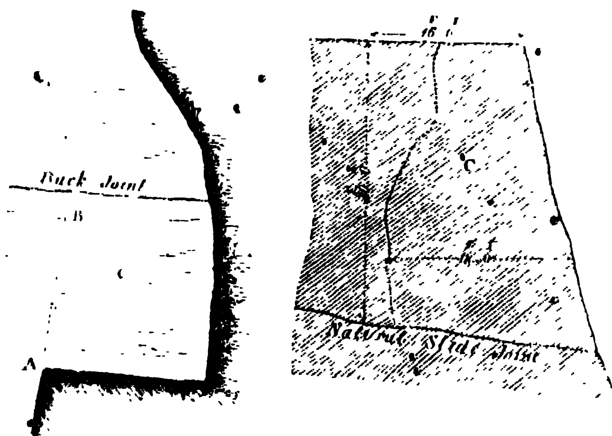
The rock may require to be cut to a particular form, as, for instance, when preparing it to receive foundations of masonry; or certain blocks of the stone may be required of particular forms or dimensions: an excess of powder may be applied to increase the shock for bringing down any loose mass in a peculiar state, or, *vice versâ*, smaller proportions may from circumstances be sufficient to produce as much effect as is required: these irregularities are very frequent, but it is not the less necessary to understand the correct principles, and not to be carried away with the idea that the whole is a mystery.

It may also be urged that there are cases where the system of working on a line of least resistance, different from that of the hole bored, cannot be followed; such, for instance, as in sinking a shaft, or cutting the first driftway of a gallery or tunnel.

This is very true, and must cause such operations to be peculiarly costly and slow; and though the rule above recommended for regulating the charges would be inapplicable, still that of taking any proportionate depth of the hole would be quite erroneous.

The system to be adopted in such instances should be to apply the mode of tamping that would give the greatest possible resistance, and to endeavour to obtain by trials the amount of charge by weight that will barely disturb such tamping; in this way the full effect of the powder will act upon the rock, and where that is not very great, a second shot from the same hole will be sure to be very decisive.

PLAN. FIG. 10. SECTION.



Among the cases not admitting of fixed rule, and where a great deal *must* depend upon the intelligence and experience of the directing quarryman, is that of irregularity of joints, or seams.

The following instance will explain this:—

A hole A, B, fig. 10, of 4 inches diameter and 16 feet

deep, was bored to the back of a projecting mass of granite, and 6 feet above a natural slide joint, as shown in the plan and section.

Had there been no projection, nor any joint to afford an advantage, it would have required probably 182 lbs. of powder to break through a resistance of 18 feet; but as it was circumstanced, between 35 and 36 lbs. (occupying 7 feet of the hole) broke off and overturned an enormous mass C, cutting it down as shown by the dotted lines: the fragments of course were large, one piece containing 80 cubic yards; and were very appropriate for cutting into ashlar of large dimensions.

Another instance tried at Dunmore East, near Waterford, may be given of the force of the action of powder, even in an open joint: the same experiment also incidentally serves to illustrate another object of inquiry.

Fig 11.—(Plan.)



The rock was a very hard conglomerate, in fair parallel beds; the surface was even; the side H, H, fig. 11, had been already excavated; there was a joint or bed, parallel to the surface, and 7 feet below it. A hole *a*, of 2 inches diameter and 6 feet deep, had been loaded with 1 lb. 14 oz. of powder, (15 inches,) and made a straight crack *c c*, and to *k*, of 14 feet long, and down to the bed.

A trial was then made, whether openings might not be directed to particular lines: 13 plug-holes were drilled along the line + + + 8 inches deep and 1½ inch diameter; a 2¼-inch hole was then bored at *b*, to a depth of 5 feet 10 inches, and loaded with 4 lbs. (2 feet) of powder: when fired, the line was opened very nearly along the line of the plug-holes; the separation did not exceed half an inch.

The hole *b* was then cleared out, and loaded with 8 lbs. of powder, and the explosion sent the whole mass forward upwards of 2 feet without any new fracture; the cubic contents of the mass being 663 feet, weighing about 51 tons.

In most extensive quarries of stone, much of the practice must depend upon the intelligence with which advantage is taken of the position and nature of the

joints and fissures: still many errors are committed from a want of knowledge of the best application of powder to a perfectly solid mass; and in cases where the mass to be removed is small, or the openings to be made, confined, but little advantage can be gained by the joints, and the application should be chiefly to given charges for lines of least resistance.

The advantage obtained by joints is one reason for rather reducing the calculated amount of charges, particularly in large explosions; because although nothing that is not perceptible can well *augment* the force of resistance, fissures or joints that may not be seen on the surface may have the effect of *reducing* it.

It would be of much advantage in many cases, if the powder could be placed in a more compact form, than occupying a considerable length of a hole of comparatively small diameter: the position it must assume in these holes is generally unfavourable for producing the best effect, and in some cases renders it impossible to apply so large a charge as would be desirable; but no practical mode of enlarging the space at the bottom of the hole has yet been contrived, except perhaps by successive explosions from the same, as practised at Gibraltar.

It may be assumed that 1 lb. of powder loosely poured, but not shaken or compressed, will occupy about 30 cubic inches; a cubic foot weighs consequently about 57½ lbs.; although different quantities are given in different Tables of specific gravity: if close shaken, powder will go into a smaller compass.

The following Table from Colonel Pasley's Memoranda on Mining will give the means of calculating the space occupied by any given quantity of powder in round holes of different sizes from 1 to 6 inches.

Diameter of the hole.	Powder contained in one inch of hole.		Powder contained in one foot of hole.		Depth of hole to contain 1 lb. of powder.
inches.	lbs.	oz.	lbs.	oz.	inches.
1	0	0·419	0	5·028	38·197
1½	0	0·942	0	11·304	16·976
2	0	1·676	1	4·112	9·549
2½	0	2·618	1	15·416	6·112
3	0	3·77	2	13·24	4·244
3½	0	5·131	3	13·572	3·118
4	0	6·702	5	0·424	2·387
4½	0	8·482	6	5·784	1·886
5	0	10·472	7	13·664	1·528
5½	0	12·671	9	8·052	1·263
6	0	15·08	11	4·96	1·061

In practice, the holes are somewhat irregular; this Table however will be sufficient to ascertain, nearly, the depth required for any charge.

Let us now consider in detail some of the operations and materials employed in the blasting of rock.

BORING THE HOLES.

The best means of expediting in point of time the operation of blasting, would be by any contrivance that would render the boring of the holes more quickly executed.

The ordinary implements used for this purpose are, the jumper or cutting-tool, the hammer, and the scraper.

There is much discrepancy in the account given in different places, of the time required for boring holes; arising from differences in the precise quality of the rock, the mode of working, and the different bases of calculation.

The following, obtained from John Mac Mahon, Esq. of Dublin, is the result of some considerable experience in quarries of granite of good quality at Dalkey, in the neighbourhood of Dublin.

" 3-inch jumpers, used in boring holes from 9 to 15 feet deep; 2 men striking, and 1 man holding and turning the jumper, bored on an average 4 feet in a day, or 5 feet with a 2½-inch jumper, which was frequently used for boring the same depth.

" 2¼-inch jumper, for holes from 5 to 10 feet deep; 3 men as above would bore on an average 6 feet each day.

" 2-inch——holes from 4 to 7 feet deep; 3 men would bore 8 feet of such holes.

" 1¾-inch——holes from 2 feet 6 inches to 6 feet; the 3 men bored 12 feet.

" In working the two last classes, a strong boy will answer to turn the jumper instead of a man.

" 1-inch jumper, for breaking the fragments of rock to smaller pieces; 1 man bored 8 feet per day.

"The waste of steel and iron was nearly as follows:—a 3-inch jumper took for its bit 2 lbs. of steel, with which it would bore 16 feet, on being dressed or sharpened 18 times; waste of iron 18 inches to each steeling, or 1⅛ inch for each foot bored.

2-inch jumper took $1\frac{1}{4}$ ℔. of steel,
$1\frac{3}{4}$-inch ,, ,, $\frac{3}{4}$ ℔.,
1-inch ,, ,, 3 oz.

"They would all bore from 18 to 24 feet with each steeling, and require to be sharpened about once for every foot bored.

"The weight of the hammers used in boring with each class of jumper was as follows:

18 ℔. hammers for 3-inch jumpers,
16 ℔. ,, ,, $2\frac{1}{2}$ and $2\frac{1}{4}$-inch,
14 ℔. ,, ,, 2 and $1\frac{3}{4}$-inch,
5 to 7 ℔. ,, ,, 1-inch, used by one man.

"Churn jumpers, so called from the manner in which they are worked, from 7 to 8 feet long, with a steel bit at each end; general diameter, $1\frac{3}{8}$ to $1\frac{1}{2}$ inch. Two men would bore with them about 16 feet per day."

These last are much more efficient than those struck on the head with a hammer, and are sometimes used with a spring rod and line. They are applicable to holes that are vertical, or nearly so, and to rock that is not too hard: in the granite at Kingstown they were abandoned on account of the edges turning so fast, that the frequency of the necessary sharpenings gave the advantage to the use of the hammer: where they can be used, the work will be performed at a far more rapid rate than even above mentioned. In boring Artesian wells to great depths the application of the tool is entirely on this principle.

A still quicker mode of boring would be by *drilling* the holes, if it were feasible. It has often been proposed, but the cutting edges of the tools will not stand in any kind of stone.

Where charges have been exploded without blowing out the tamping, it may be very desirable to bore the latter out for the purpose of introducing another charge; in such case the hole need not be of the size of that originally made, as 1 inch bore will be adequate at any time.

In clay tamping, a hole may be bored out with the jumper and hammer at the rate of about 26 minutes for 3 feet. Broken stone tamping will be bored out at the rate of 20 minutes for 3 feet.

A very few trials were made to bore a hole through clay tamping with an

auger; the labour was less, as fewer men were necessary; the time consumed was somewhat more, but the tool was capable of improvement, and the men were new to its use.

It is conceived that augers, properly constructed, may be used to advantage in re-boring through clay tamping for successive blasts from the same hole, to the gain of a saving in time and labour, and avoiding the application of water, which is necessary with any kind of jumper.

In case of a miss-fire it is a very dangerous practice to re-bore the hole, and has occasioned very many bad accidents; it is very properly usually forbidden altogether. If the hole be vertical, or nearly so, and the needle or fuse hole can be cleared, so as to *ensure* a thorough wetting of the charge, by pouring water down, it might be done with safety; but sometimes the very object of the quarryman is to save the powder,—a very unworthy one for which to incur the great risk of killing or maiming two or three workmen.

To prevent the loss of any large charge in this way, a hole is sometimes bored on one side, and within a few inches of the one that has failed, to the same depth as its charge, and being loaded and exploded, has had the effect of igniting the other also.

An apparatus for boring to considerable depths has recently been introduced into this country from mines in Germany[4] by Charles Vignoles, Esq., C.E., which it is believed is far more efficient than any hitherto employed in Great Britain.

This machinery has been in operation, it is believed, on the Manchester and Sheffield Railway, of which Mr. Vignoles was the engineer; its direct application being to bore into and ascertain the precise qualities of the strata through which the great tunnel (3 miles in length) will be carried, which is to form the communication through the mountain ridge that divides the eastern and western inclines of England.

The principal feature in the process is that the cutting tools are attached to a heavy weight, and worked by a rope, instead of by rods with screw joints.

The rope is wound round a cylindrical roller by a winch, and there are several ingenious contrivances in the details and parts of the machinery, that tend to facilitate the operation.

[4] It is said that boring on a similar principle has been long used in China.

OF THE POWDER AND THE CHARGE.

Gunpowder used for the blasting of rock is notoriously of inferior strength to that sold for sporting, or manufactured by Government for the army and navy; and there is an impression (I believe nearly universal) that it is right that it should be so, not merely because pound for pound it is cheaper, but because it is thought to be positively better for the object, on account of its less rapid ignition, and assumed quality of giving what the miners call a *heave*.

This opinion appears to be founded on a fallacy.

Inferior powder *cannot* be used in war, or for sporting, without the disadvantage being immediately apparent; while in blasting it can be made to answer the purpose: this, with its comparative cheapness, has led no doubt to its being introduced and constantly made use of, without much investigation as to the policy of its employment in preference to a material of superior strength.

The argument used in its favour is, that by igniting slowly in comparison with the other, the power is more forcibly and efficiently applied for the required object, than by the rapid shock of the superior powder, such as is undeniably requisite for impelling projectiles.

This reasoning would seem to imply that the rock will be opened better by a force of *pressure* than by that of a sudden *shock* or *blow*; which however may be disputed, even supposing, what is probably not the case, that the elastic vapour generated by either is the same. Rock being of a brittle nature, it is reasonable to suppose that the sudden violent shock would make more extensive cracks, which is the great object, than a more slow action.

The following are the observations I have been able to collect on this head; and they tend to confirm the impression of the good policy of employing stronger powder for blasting, even at increased prices: more research, however, would be necessary to establish the fact entirely, and to fix the relative value of each gradation in quality.

Having procured from great contractors and respectable dealers eleven samples of Merchants' blasting powder, stated to be that of the principal manufacturers, they were analysed, proved with the éprouvette mortar and éprouvette gun, and compared by the bursting of shells: the results will be seen in the annexed Tables.

Qualities and Proofs of eleven samples of Merchants' blasting powder, as compared with Government cannon powder.

Number of samples.		Results of analysis per centage. Nitre.	Sulphur and Charcoal.	Loss.	Total.	Ranges from éprouvette mortar. 1st.	2nd.	Mean.	Number of degrees and tenths by éprouvette gun.	Remarks.
		grs.	grs.	grs.	grs.	ft.	ft.	ft.	degrees.	
1	Said to be of same manufacturers, but procured from different dealers.	72½	25	2½	100	97	93	95	16·6	Highly impregnated with foul salts.
2		66	32½	1½	100	142	137	139½	17·3	Contains foul salts, but not so much as No. 1. —Deficient in nitre.
3	. . . . . .	66	32	2	100	150	91	120½	18·7	Deficient in nitre, and highly impregnated with foul salts.
4	Two qualities, from the same manufacturers, but procured from different dealers.	66½	31½	2	100	79	99	89	14·6	Same as last.
5		75	24	1	100	125	148	136½	..	Nitre very impure.
6		73½	25½	1	100	83	67	75	..	
7	Two qualities, same manufacturers.	73½	21½	2	100	118	113	115½	17·7	Highly impregnated with foul salts.
8		66	32	2	100	43	55	49	16·9	Do., and deficient in nitre.
9	Three qualities, same manufacturers.	73	25½	1½	100	169	158	163½	12·0	Contain foul salts, but by no means so much as the preceding samples.
10		73	25½	1½	100	128	148	138	to	
11		73	25	2	100	127	107	117	15·2	
	Good Government cannon powder.	75	25	,,	100	,,	,,	265	21·0	Ingredients pure, and very intimately mixed.

The best proportion of nitre (the most valuable ingredient) is 75 per cent.

The éprouvette mortar is 8 inches in diameter, and is charged with 2 ounces of the powder, and an iron ball of 68½ lbs. weight; the Government good cannon powder gives an average range of 265 feet. The Government powder somewhat deteriorated, and reserved for blasting, gives a range of 240 feet.

The éprouvette gun is of brass; its bore 1¾ inches in diameter and 27·6 inches long; it weighs 86½ lbs., and is suspended from a frame: being charged with 2 ounces of the powder, without any shot or wadding, it is fired, and the extent of the recoil is measured by an index on a graduated arc.

The éprouvette gun is considered to be rather adapted to try the strength of *fine grained* powder than of the coarse; the fine grained Government Rifle powder will give 25 or 26 degrees; the Government good cannon powder 21 degrees; that tried at the same time with the above, 20·5. It is extremely probable that in many instances of these coarse grained qualities, and of the Merchants' powder, igniting slowly, much of the charges may have been thrown

out from the gun in each case unignited, and perhaps in some degree from the mortar.

Some discrepancies will be observed in nearly all proofs of gunpowder, but rarely to the extent that will be noticed in this Table: they show, however, how very unequal may be the qualities of the article as obtained at different times, from different dealers, and subject to a variety in their condition from modes and time of keeping; and they also exhibit a very strong presumption of universal inferiority.

Experiments on the relative strength of Government cannon powder and Merchants' blasting powder, by the bursting of 5½-inch spherical case shells.

Government Cannon Powder.					Merchants' Blasting Powder.				
Number of experiments.	Number of shell.	Charges of powder.	Effect.	Observations.	Number of experiments	Number of shell.	Charges of powder.	Effect.	Observations.
		oz.					oz.		
1	1	4	None.		4	2	8	None.	Loaded and fired warm from previous explosion.
2	2	6	None.		5	3	10	None.	
3	1	8	Burst.	Loaded and fired when warm from previous explosion.	6	2	12	Burst.	Third trial of same shell, loaded and fired warm.
8	5	7	None.		7	1	11	None.	
9	6	8	None.		12	9	12	None.	
10	7	9	None.		13	10	14	Burst.	
11	8	10	Burst.		14	11	13	Burst.	
15	12	9	Burst		17	1	12	None.	Second trial of same shell, but quite cold.
16	3	8	None.	Second trial of same shell, but quite cold.					
18	5	9	Burst.	Second trial of same shell, but quite cold.	19	6	12	Burst.	Second trial of same shell, but quite cold.

The comparative strength by this mode of trial would seem to be about 9 parts of the Government, equal to 13 of the Merchants' powder.

It is very difficult to obtain any very precise results from trials on the rock itself: the effects vary so greatly under circumstances to all appearance precisely simiiar, that we are driven to reason very much from analogy; and where the blasting is judiciously performed, the tamping but slightly, if at all removed, and the rock merely opened and not violently ejected, it certainly would appear reasonable that the powder showing such superiority of strength in the above-described experiments would be by far the most efficient in its action on the rock.

A few trials that were made at Kingstown to elucidate the point seemed to prove the truth of this reasoning.

Charges calculated on the basis of ½ ounce for 1 foot, and augmented in proportion to the cubes of the lines of least resistance, were exploded in a high face of very solid rock; and the result in every case was very marked in favour of the Government powder, even to the conviction of the miners present, who had previously expressed doubts on the subject.

Although the Government powder was applied to the cases which seemed to present the fewest advantages, the effect was decidedly superior, to the extent of usually dislodging a mass of rock; whereas the Merchants' powder in no instance did more than make cracks and fissures.

If the truth of this suggestion be acknowledged, the following advantages would attend the use of the superior powder.

1. As smaller quantities would go farther, the stock for consumption would be easier to stow away and to carry.

2. Greater effect would be produced with a smaller amount of labour, and, what is of more consequence in many cases, of time in boring holes.

3. By occupying a smaller space in the bottom of a hole, an increased resistance in the tamping would be obtained by its greater proportionate extent.

4. The Government powder, and the superior kind made for sporting, (the former in particular,) are *much less* subject to deterioration from keeping, than the ordinary blasting powder: this would effect a very desirable improvement, but it is not an absolutely necessary consequence of their being stronger, because the best preserving powders are not always the strongest.

According to Dr. Ure's Chemical Analysis, there is not much difference between the mixtures of the Government Waltham Abbey powder, and those of the *first class* of *sporting* powder of the private manufacturers; the Government powder, however, resisted rather the best the hygrometric influence, that is, would absorb less atmospheric moisture, and consequently be best for keeping.

In the works carried on by the Royal Engineer department, the powder is usually from the Ordnance stores, sometimes being perfectly good, or even if deteriorated to the degree for its being appropriated to blasting, it is still much stronger than the Merchants' blasting powder.

Fine grained powder made with very superior care, and at superior cost, is manufactured for the Rifle Service by Government, and for shooting by private manufacturers: but it would be too costly in proportion to its increased

superiority, and some of its properties not being necessary for blasting, it is considered that the best *cannon* powder would be the most advantageous to employ.

With regard to price, blasting powder is sold by the dealers in the country at about from 50*s*. to 75*s*. per 100 lbs.; while nearly as good powder of this nature as can be made, such as the Government cannon powder, might be sold *by the manufacturers* at between 50*s*. and 60*s*.: supposing therefore that the cost, including the removal, the *dealers'* expenses and profit, should be one quarter or one third more than at present, the question will be, considering the advantage of using this superior kind, and the proportion which the cost of the powder bears in the general expenditure of blasting, how far, and under what circumstances, it might be desirable to incur that increased expense, making allowance at the same time for the smaller quantity that would be consumed.

It certainly would be most desirable to know precisely what are the best qualities for blasting powder, and how to test those qualities; for at present it is an article that must be taken entirely on the credit of the manufacturer or dealer; the purchaser remains quite in the dark as to its real value, even *after it has been used.*

In some respects, persons engaged in blasting do show a distrust as to the quality of the powder: it has been observed that many refused to purchase from some manufactories where it was cheaper than usual, alleging that it was an inferior article; but no satisfactory account could be obtained as to how that inferiority was measured, nor why the other kinds, which are notoriously inferior in strength to Government cannon powder, should be decided to be precisely what is best.

Should it be thought advantageous to employ a stronger quality, it would be necessary to have some ready means of proving it, otherwise the article might remain the same at an increased price for an assumed superiority.

This it would not be difficult to effect, as, with the sanction of the Master-General and Board of Ordnance, the means of trial might be prepared at every Ordnance station, and samples there proved at fixed periods, for any party, on payment of a sum for the expenses, which would be trifling; or without the intervention of the Ordnance, the means of proof are neither very costly nor troublesome; but the other mode would be more satisfactory, as the trials would be sure to be carried on with accuracy and impartiality, and the results obtained would be on authority.

Founded on the same reasoning of the advantage of more gradual ignition,

and almost leading to the assumption that the blasting powder in its present state is even *too good*, is the assertion that will be found in all books on the subject, namely, that a mixture of fine and dry sawdust of elm or beech with the powder, in the proportion of $\frac{1}{3}$ of sawdust for small charges, and $\frac{1}{2}$ for large, will produce as good results as equal quantities of powder alone.

It is not assumed that the effect is produced by any decomposition of the sawdust, but simply by giving a little more space, and by dividing the particles of the charge, causing them to ignite more gradually, and thus to act with greater force on the rock, than by the more sudden explosion.

No account is given of any defined experiments tending to prove this fact; on the contrary, every trial affording positive results is against it: such a mixture has been tried in guns, and produced no useful effect whatever; and though of very simple application, it does not appear that in any place there has been a continued use of it.

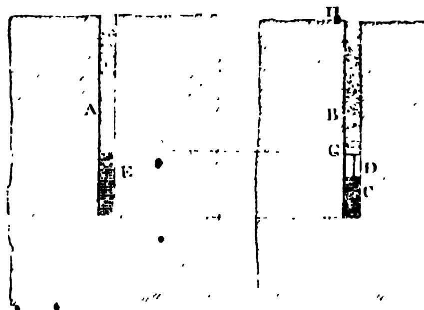
There is indeed a deception in the first instance in the supposed proportions; for a mixture of two equal measures of the two ingredients, the sawdust being, as required, very fine and dry, and the powder of the usual large grain, will not fill above $1\frac{3}{4}$ of the same measure; consequently two measures of the mixture will contain nearly $\frac{1}{8}$ more powder than calculated upon: thus if two measures, each capable of containing 8 ounces of powder, be filled with the mixture of equal measured proportions, the quantity of powder will be nearer 9 ounces than the 8 calculated upon.

Altogether I feel little doubt of the application of sawdust being of no real value.

Another theoretical refinement, that is to be found in all works on blasting, is, that if a hollow space be left adjoining the charge, a much greater effect will be produced, provided always (and it is essential to bear it in mind) that the tamping be as substantial, and to *as great* extent, in the one case as in the other.

Thus in two holes of similar dimensions, the charge C, fig. 12, with a hollow space D over it, will produce as good an effect with $\frac{1}{2}$ or $\frac{2}{3}$ the quantity, as at the full charge E fully tamped, provided the tamping B, from G to H, be as good and as deep as that at A.

(FIG. 12.)



An increased effect will certainly be produced by such hollow, in the same manner

as with guns which are frequently burst by the occurrence of a hollow between the powder and the shot, but there must be great reason to doubt its *practical* utility: no accounts are given of the well-defined result of actual experiment, nor are any rules attempted to be laid down for the extent of the hollow spaces in proportion to the quantity of powder in the charge, &c. to produce useful effect; and yet these must be matters of consequence; nor is it any where stated that it has been ever practically continued to be used, notwithstanding the great saving of powder professed to arise from the adoption of this principle.

In large charges, the space that could be left would be too small to produce any useful effect; and in small charges, the more simple, quick, and cheap way, would be the full charge of powder.

This and the sawdust are among the refinements adverted to in books (on this as on many other subjects), but seldom, if ever, put in practice.

Another mode of improving the power of the charges of powder has been employed, it is said, in America, which seems somewhat more reasonable than the application of sawdust. It is the mixing of a quantity of quicklime in a proportion of about $\frac{1}{4}$ with the powder, on the principle that it will absorb any little moisture in the powder, and itself produce some additional vapour in the explosion. It is stated, however, that it must be used soon after the ingredients are put together, it having been remarked that if left mixed for a whole night the powder was deteriorated, owing, as imagined, to the impurities of the saltpetre of which the powder was composed.

This again, by adding another ingredient and operation, reduces the simplicity of the work, and probably in a far greater degree than any advantage to be produced would compensate.

With reference to the quantities of powder to be employed in blasting, different systems are adopted.

In quarries worked for large stones, and in great quantities, sometimes very large blasts are considered advantageous.

In those near Kingstown, where the granite stones for ashlar work are squared by the contractors to from 40 to 60 cubic feet each, 50, 60, and 70 lbs. of powder were frequently exploded in a single blast, sometimes filling two-thirds of a hole of 4 or $3\frac{1}{2}$ inches diameter, and perhaps twenty feet deep.

They have been applied generally where a projection of considerable height

or length, showing joints in large features, offered a prospect of bringing down some enormous mass; and in this way they were usually very successful.

To give an instance of one;

The hole was 19 feet 7 inches in depth, and 5½ inches diameter; the charge, 75 lbs. of powder, filled 8 feet 10 inches of the hole, having consequently 10 feet 9 inches of tamping.

The mass that was brought down, or thoroughly shaken and rent, measured, on a rough calculation, 1200 cubic yards, or 2400 tons. The cost was calculated at £6 15*s*. 8*d*., thus,

2 men, 14 days, at 1*s*. 8*d*. each . .	£2	6	8
1 ditto, 14 days, at 1*s*. 6*d*.	1	1	0
75 lbs. powder	2	0	0
Fuse	0	2	0
Smith's work, iron, steel, &c. . . .	1	6	0
	£6	15	8

Of course there was a great deal of after-work, and small blasts required for the separation of the large masses of which this shaken rock consisted, and reducing it to manageable shapes and sizes; but the work was greatly facilitated by this first effect.

At Gibraltar, the military miners under the Royal Engineers work on quite a different system.

The rock there is a peculiarly hard limestone marble: to bring down large masses, they bore their holes usually to about the depth of 9 feet with 2½-inch jumpers, and load them with about 4 lbs. of powder; the explosion has no apparent effect, but the rock is shaken below: the needle hole is cleared out, and the hole again filled, when it will take perhaps from 8 to 12 lbs., and is fired again: a third charge with perhaps 20 to 30 lbs. is fired in the same manner, and sometimes a fourth, till the rock is very greatly separated and rent to the extent of 10, 20, or 30 feet in different directions. If the needle hole or tamping be deranged before the final explosion, it is bored out and re-tamped.

Under all ordinary circumstances I should much prefer the principle of this system to the other; it is more gradual and systematic, would require less labour in boring, and is less subject to waste of powder, or the violent projecting of stones.

In some rocks it may be liable to one objection, which is, the chance of any of the preliminary explosions tapping a spring or vent for water into the hole: no such springs are found at Gibraltar, but they are at Kingstown.

If the holes should not be vertical, or nearly so, (which it seems they always are at Gibraltar,) the tamping must be bored out at each explosion, to enable the next charge of powder to be introduced.

The prevailing fault in blasting is the using of too much powder.

If the tamping be not blown out by the smaller charges, a very useful effect will have been produced on the rock by every explosion, even although the rock be not *apparently* much affected; the tamping will be easily bored out sufficiently to admit a fresh charge, which, being introduced and re-tamped, will be found to be very efficient.

The object is generally to loosen and bring the rock down in large masses, and not to shatter it into fragments: even for small stone, such as for road metalling, &c., it is better to bring out first large masses, and subsequently to divide them, either by small blasts with powder, or by crowbars and sledges.

OF LOADING.

The ordinary manner in quarries of loading and firing the holes that have been bored is,

I. To dry out the bottom, if necessary, with little wisps of hay.

II. To pour in the powder till it fills a certain number of feet or inches of the bottom of the hole. If the hole be vertical, or very nearly so, the powder will drop in pretty clear to the bottom; but if it be on an inclination, and not very steep, the powder must be scraped down, professedly with a wooden ramrod, but frequently with an iron scraper. If the hole be horizontal, a scoop is used, which is open at top, and by being turned round at the end of the hole leaves the powder there. If the hole incline upwards, a cartridge is employed.

III. A needle is then introduced, the point of which is let well into the charge of powder, and the top with a handle or eye extending to the outside of the hole

IV. A little wadding, either hay or straw or turf, is inserted over the powder.

V. The tamping over the wad is very generally of the small fragments of the quarry stone and its dust, (unless there be in it flint or other substance that *notoriously* strikes fire, in which case broken brick is commonly used,) rammed

down, by one or two inches at a time, by means of an iron rod, or tamping-bar; the needle is frequently turned to prevent its becoming fixed.

VI. The last inch or two is filled with damp clay.

VII. The needle is carefully pulled out, and the opening it has left is filled with loose fine grained powder; or with a long series of connected straws filled with powder, into the upper end of which is inserted a small piece of touch paper that will burn about ½ a minute, which is lighted and communicates the fire.

The touch paper is made by the quarrymen themselves, by soaking coarse paper in a strong solution of saltpetre, or gunpowder, and then drying it.

The following is an expressive account of the process, as written by a quarryman of much experience.

"The method of blasting is in every place nearly the same, as far as I have been able to make observations, and I have had charge of such work in Scotland, England, Wales, America, and, lastly, in Ireland. Different quarrymen may, it is true, not agree in every thing; for instance, some prefer a small piece of dry turf for a wad over the powder before they commence ramming; others prefer hay or straw; but in ramming every one uses the same kind of stuff, that is, small pieces of any stone (that has no flint in it) that will go into the drill hole; but in deep holes ramming sand will do as well as any thing.

"The usual method of blasting is very simple, and is as follows: first, to drill the hole, say 3 feet deep, 1½ inch bore; in common cases 6 inches powder will be sufficient in the bottom; then in with your needle, then your wad of turf or hay, &c.; then two or three blows with your rammer, and then in with a handful of small stones; four or five blows more of your rammer, and so on till you fill up the vacuity above the powder within 1 inch of the top; then fill said 1 inch with a bit of moist clay (not too wet), and then extract your needle; lastly, fill up the needle hole with fine powder, or, what is safer, put down straws filled with powder, and apply your match, to which set fire, and run as fast as you can, and you have the whole of it."

Nothing can be more, 1st, uncertain,—2nd, wasteful,—3rd, dangerous,—4th, unscientific, than the whole of this process.

1st. Missing fire occurs frequently,—some obstruction will arise in the needle hole; any moisture in the hole, or wetness in the atmosphere, will affect so small a quantity of powder as composes the train; loose powder for the train

cannot be introduced into any but such as are vertical or very steep, and straws of any length are not easily passed through to the charge. All these and other circumstances must create much uncertainty.

2nd. To say nothing of the guess-work in the proportion of the charge, there must be much waste in the manner of introducing the powder, and in the occasional missing fire.

3rd. With regard to the danger, it manifestly pervades every step from the first handling of the powder.

4th. No rule is adopted for the charge, nor for the size of the holes, nor for the depth of tamping; no knowledge acquired of the best material and mode of tamping, nor any contrivances for accelerating and simplifying the process, or reducing its danger.

To obviate in some degree these defects, the following proceedings have been adopted with success:

To allot every charge by weight, according to a scale adapted to lines of least resistance, or to the circumstances of the case.

The overseer (or, if the work be sufficiently considerable, an express powder-man) to have on the spot a strong copper canister containing from 3 or 4, to 10 or 12 lbs. of powder, with a large mouth or opening, but thoroughly secured by a well-fitted cover from spilling, accident, or weather, and with a lock and key.

He should have a set of marked copper measures that will contain, when full, just 1 lb., 4 ounces, and 1 ounce of powder, respectively;[5] a copper cylindrical tube of 3 feet, or 3 feet 6 inches long, by ¾ inch diameter from out to out; a set of three tubes of about an inch in diameter, 3 feet long each, with joints, so as to be screwed at pleasure into one length of 6 or 9 feet, or with more joints if deeper holes are employed, and so constructed that when together the interior should form one smooth surface; a copper funnel, the bowl large enough to contain about 1 lb. of powder, and the neck 2 inches long, by somewhat less than ¾ inch diameter; together with some coils of Bickford's patent fuse.

By means of the measures, the tubes, and the funnel, any specific charge of

[5] Where the blasting is constant, and the charges vary but little, such as in sinking shafts, driving galleries, &c., it might be found convenient to have charges of the most usual quantities prepared previously in papers, cartridges, or perhaps even in little boxes or chargers.

powder may be lodged *clear* to the bottom of any hole; and if horizontal, or nearly so, by pushing it in through the tubes with a wooden stick or ram-rod.[6]

One end of a piece of the patent fuse is inserted well into the powder, the other end cut off about an inch beyond the outside of the hole; a little wadding is then pressed down over the powder with the tamping-bar, and upon that the tamping in the usual manner (but with a proper material) to the top, without any necessity for the moist clay.

Most of the accidents that occur to miners arise from the first blows of the tamping-bar over the charge: to obviate this, the first 2 or 3 inches of the tamping should be merely pressed down gently over the wadding, and then the hard ramming commenced over that; this cannot injure the effect of the explosion, as it is generally acknowledged that a small vacant space about the powder tends, if any thing, to increase its power.

If the tamping-bar be tipped with brass, it will add more security, and at *very little* increased expense.

The outer end of the fuse is then lighted; there is neither difficulty, loss of time, nor extra cost or labour, by using these precautions, and obtaining all the consequent advantages; they should therefore never be neglected.

Whenever blasting is to be performed on an extensive scale within a limited space, it will be quite worth while to ascertain by a few experiments the value of the different ingredients that are to be used, or matter to be acted upon in the particular locality, as well as the best modes of applying them; such as the strength of the powder, the tenacity of the rock, the value of the tamping material, &c.: it is clear that, by proportioning these justly, so as to obtain the greatest effect with the smallest means, much time and expense may be spared.

OF THE TRAIN AND FIRING.

The inconveniences and loss of time attending the ordinary mode of laying the trains for firing the charge in blasting holes have been mentioned above.

[6] It affords one very important medium of security against accidents to deposit the powder quite clear to the bottom of the hole by means of these tubes, instead of allowing grains to hang on the sides, as they must do when it is poured in the ordinary manner, particularly in holes that are inclined, where it is easy to conceive that a *regular train* may sometimes be left from top to bottom.

It is the very worst contrived part of the whole operation of blasting; but fortunately a most valuable improvement has been made of late years by the invention of Bickford's patent safety fuse.

The use of this article is extremely simple; it is efficient in damp situations, and even under water, by using the quality prepared expressly for that object; a miss-fire is scarcely ever experienced, unless there be great carelessness, and it is a *very great* protection against accidents.

Whenever accidents have occurred (which are *extremely* rare), they have been traced to circumstances which could not be affected by the fuse; namely, to the first applications of the tamping-bar over the powder.

So large an opening for the escape of the powder is not created by the fuse hole as by the needle;[7] and, taking every thing into consideration, it is calculated that the use of the fuse is cheaper than the ordinary priming, even if the very trifling cost, or at least difference of either, could be deemed of importance.

SAFETY FUSE.

At Kingstown Harbour it was employed constantly in working with a diving bell in blasting rock for foundations in from 20 to 30 feet depth of water, and with complete success.

The following account of the great value of this invention is from a Paper by B. Mullins, Esq., an intelligent member of the firm who have the contract for the Kingstown Harbour works.

"Rock blasting operations have been for many years, and are now, carried on extensively by my firm. Bickford's safety fuse has been invariably used in those operations since the Summer of 1833. It has our entire approval, as being more certain in its effects, less hazardous in its application, and ultimately cheaper, although not apparently so, than priming in the ordinary mode. From the period of its introduction up to the present time, we have not had an accident in any of our works from blasting, although within that period 73,600 lbs. of powder have been consumed, and labour equal

[7] In firing very small charges, the opening made by the needle or fuse hole tends very much to reduce the effect. In the tamping experiments it will be observed, that of clay, and other compact tamping, portions of the top were frequently carried away; in all these and other partial removals of tamping it was observed that the principal openings were always on the side where the fuse had been.

to that of 288,719 days of one man expended; nor had we more than two or three cases of miss-fire that I can collect, and those were caused by want of caution in using improper tamping material, having stones in it which cut the fuse and severed the train. We have used of it in the interval 167,322 lineal feet.

"The cost of 167,322 feet of the fuse was £304 7*s*. 9*d*., while that of the actual quantity of powder required for the same amount of priming, namely, 35 barrels, would be £105, besides the labour of the application of the latter."

Then follows a comparison between the old system of loading and firing, and the mode with the fuse.

After describing in detail the old practice (that indeed still used in most places), the statement continues thus:

"In the application of the fuse the charge may be lodged at any required depth in the rock. We lately drove a hole with a 5-inch gauge 20¼ feet horizontally into the face of the cliff at Dalkey, and charged it with 85 lbs. of powder, by which we released 2000 tons of solid rock, a quantity far exceeding what could be displaced by vertical or oblique bores. Straw tubes could hardly be made of so great lengths, and were it practicable, there is so great a loss of time, and so much uncertainty in using them in horizontal holes of much less depth, that they bear no comparison in facility of use to the fuse, which effectually supersedes the tedious and hazardous employment of the needle, and is a perfect preventive against premature explosion or miss-fire, wherein the old methods are particularly defective.

"It has this further advantage, that any number of shots may be simultaneously fired, whilst with the straw tubes and match paper not more than three, with a probable chance of escape to the men employed.

"In wet quarries the fuse is quite as effective as in dry: where wet joints are met with in boring, which frequently happens, the holes fill with water, and must necessarily, by the old methods, before being charged, be rendered perfectly dry; this is accomplished by wrapping coarse tow or mop thrums round the end of a stick, and mopping out the water; the finest argillaceous clay is then kneaded into a paste, and worked constantly upwards and downwards by the tamper struck with the hammer, and continued until the blaster is satisfied of having staunched the leaky joints in the hole: this being done, the hole is then cleared out with an iron scraper, made dry, and charged; and

after all this labour success is doubtful. A man often spends half a day drying, tamping, and charging a hole in this way to no purpose, the powder having got wet.

"In these cases the fuse furnishes an effectual remedy; a water-proof bag containing the powder, and having a sufficient length of fuse closely tied in its mouth, is pushed home to the bottom of the hole, which is then tamped and fired with as much certainty and effect as in dry work.

"Blasting in deep water by means of the diving bell is rendered comparatively easy by the use of the fuse, as compared with the tedious, costly, and ineffective process heretofore practised.

"In the old way, the charge was lodged in a tin canister in the bored rock; in this canister a small tube was fixed, and raised joint after joint, until the bell was elevated above the water's surface; then a small piece of iron made red hot was thrown into the tube to fire the charge in the canister. What the effect produced may have been, I cannot say of my own knowledge, not having seen those operations; but I have been informed that, except in insulated rocks, it was of little use. The canister and the joint of the tube adjoining were blown to pieces, and most of the joints more remote were flattened by the collapse of the water, so that new canisters and tubes were necessary for every shot.

"The fuse employed in blasting under water is somewhat different, and more expensive than the other, and is called sump-fuse; it is used in the following manner:

"A water-proof charger or bag, containing the powder, with a piece of fuse 5 or 6 feet long, closely tied in its mouth, is dipped in boiling pitch[8] to secure the orifice from wet; the charge is then put into the bore hole, which is tamped with sand, or the fine chippings of the stone-cutter's waste, and the fuse, the upper end of which is retained in the diving bell, being set fire to, is thrust out under its edge into the water: the bell is then by signal removed 8 or 10 feet out of the way; the fuse burns through the water, and explosion follows; the proximity of the bell to the blasted rock, without endangering the workmen, enables them to resume their operations with little or no delay.

[8] A *perfect* water-proof composition for this purpose is made of

8 parts by weight,		pitch,	melted together, but not boiled.
1 do.	do.	bees'-wax,	
1 do.	do.	tallow,	

"In founding the Commercial Wharf wall (a considerable part on rock) in 22 feet water at low water of Spring tides, and in clearing for abutment for setting frame for the eastern pier head in 28 feet at low water, (the rise of tide 12 feet,) we pursued the method above described with success.

"Having obtained a list of all the men who had been killed, or badly wounded, by the old methods of blasting at the quarries for the Kingstown Harbour works, previous to the use of the fuse, I annex it."

The list referred to of accidents under previous contracts, for the first 15 years, contains the names of 30 individuals, two of whom were twice injured, making 32 casualties, consequently more than 2 per year; it includes 7 killed, 4 loss of one eye, 1 loss of both eyes, and 20 injuries; while during the 8 years of the present contract, there has been but one man injured, and that before the fuse was introduced.

In order to test the extent of applicability of this composition for blasting under water, pieces of the quality prepared for it (called sump-fuse), which is somewhat thicker than the ordinary kind, being about $\frac{3}{10}$ of an inch thick, were kept immersed (except the upper ends) for different periods up to upwards of 16 hours, and were then found to burn throughout with their ordinary force: no trial was made beyond that time.

Pieces 25 feet long, (their usual dimension,) having one end inserted into a few ounces of powder enclosed in a water-proof bag, were tied to long chains; the powder bag was lowered into the water by a weight, and the other end of the fuse being lighted from a boat, the whole was lowered again until the weight touched the bottom in 39 feet depth, and each time burned through and exploded the powder in 13 or 14 minutes. In order to get a greater length, an extra kind was procured in 51 feet and 52 feet lengths; it was apparently expressly made, and thicker than the other, being about $\frac{5}{8}$ of an inch in diameter.

This succeeded perfectly in every case; but being provided for the purpose, it was not considered so satisfactory a trial, and appears to be unnecessary, considering the efficiency of that usually sold.

The common fuse (that not prepared for water) was tried, and on some occasions, when lighted very soon after being immersed, would burn through many feet under water, but frequently only a short distance; it is manifestly not adapted for water, (and not assumed to be so,) but it is perfectly efficient in damp situations, if fired without much delay.

There is one great merit in this fuse, namely, that the improvement is gained without the least sacrifice of simplicity; on the contrary, it is much easier to apply, than any other process.

The only inconvenience attending its use, of which I am aware, is the length of time it takes to burn any but short pieces.

It burns at the rate of from 2 to 3 feet per minute; and as a minute usually affords ample time for the person firing to remove to a sufficient distance, there is a delay and an impatience created in watching the longer terms, particularly when it amounts to 3 or 4 minutes, or more.[9]

This lengthened time of burning would quite preclude its use for many military mines, where the explosion must take place at a particular instant.

In blasting under water, as it can only be lighted in the bell, or at the surface if the bell be not used in firing and the water deep, the time consumed in burning the fuse would be very inconvenient.

FIRING BY A VOLTAIC BATTERY.

Charges of powder have been fired under ground, as well as under water, and to considerable distances, by the voltaic battery.

It is to be presumed, however, that the distinct machinery for this purpose, the expense, and probably some degree of nicety in its arrangements, even after all the improvements that have been made at Chatham by Colonel Pasley, would render it inapplicable to ordinary purposes; although for firing *very large* quantities of powder, under very peculiar circumstances, it has been considered very useful. The tamping by this mode would be much more complete and substantial, having only two thin wires through it; and by the very instantaneous effect produced, even at varying distances, simultaneous explosions that are impossible by any other means might be effected by this mode of ignition.

MODE OF LIGHTING A TRAIN IN SHAFTS.

Under many circumstances the manner adopted for *lighting* a train is a matter of some consequence.

[9] The fuse burns slower through a tamping of loose sand, than through a tough material well rammed, but it is not extinguished by it.

At the bottom of deep shafts, or of long small galleries where there is no shelter for the man who applies the light, the touch paper, German tinder, or match of whatever kind, must afford time for him to get completely out of the way. It is attended with some difficulty to secure that object, without wasting time in doing so, by allowing too long an interval, but the latter must be the usual, as the only safe alternative.

The safety fuse has an advantage in this respect, as its period of burning can be more regularly calculated than that of any other match usually resorted to.

A French engineer has proposed and employed a manner of remedying this inconvenience, as far as regards blasting in a shaft, which would appear to be useful where the safety fuse is not employed.

One end of a wire is fixed temporarily into a little powder connected with the train, the other end in a coil being at the surface of the ground.

The wire is carefully straightened up the shaft from any sharp twists or bends; a piece of German tinder is passed round it, forming a very loose ring, and, being lighted, is let go, and drops down on the powder.

The wire may of course be constantly suspended to the side of the shaft, and fixed and applied from time to time as wanted; being lengthened from the coil above as occasion requires.

To facilitate the descent, if necessary, a small weight might be easily added, to the under part of which the lighted match could be fixed.

MEANS FOR PREVENTING SMALL STONES FLYING ABOUT IN BLASTING.

A great loss of time and labour is experienced in quarries and other confined situations, arising from the necessity for the workmen to retire to a distance at every blast; not only those engaged in the precise operation, but all others who can be at all supposed to be within reach of its effects.

This is a greater evil than what is perhaps commonly thought.

I have myself been in a great quarry, and in the course of half an hour seen 20 or 30 men, at given signals, retire two or three times from five or six different parts at which they were at work, to which they went leisurely back again after each explosion or ascertained miss-fire.

There is another occasion where the necessary retiring of the miner from the effect of a blast is attended with peculiar inconvenience; that is, from the bottom of a shaft, in which case he has to be drawn up to the top.

When a better mode of applying the charge shall be generally understood, there will be fewer occasions of the projection of stones, but there must always be some; any remedy for this waste of time, therefore, must be very valuable.

QUARRY SHIELDS.

In some quarries in the neighbourhood of Glasgow they are in the habit of frequently applying a piece of old boiler iron, of about 2 feet 6 inches square and ¼ inch thick, over the hole when fired, which acts as a shield, and in small blasts so far prevents any flying of loose stones about, that the men take much less precaution in moving out of the way on those occasions, than when it is not used.

As they have horizontal as well as vertical faces to work on, the shield is suspended over the horizontal holes, and laid flat over those that are vertical; in the latter case a large stone or two, if at hand, is frequently placed upon it.

This application might be very useful under particular circumstances of blasting; for instance, where the blasts are generally small, and in confined situations. In a shaft, where the holes will be all probably vertical, or nearly so, and the blasts not large, a good shield could be placed over every hole, and weighted either with stones, or with one or two half-hundred weights, kept in the shaft for the purpose. On trial at the particular place, this might be found to give such *certain* security, that the miners would not require to be removed more than a very short way above, either by the bucket, or by a ladder, which would lead to a very great saving of time, labour, and expense.

When not employed, the shield could be placed out of the way on its edge against the side of the shaft. In galleries, also, time might be saved in a similar manner.

It may be difficult to define the precise kind of shield, and manner of application, adapted to all circumstances; but the contrivance is simple, and in very many situations might be arranged to give perfect security, and with very little trouble.

ON TAMPING.

The desideratum in tamping is to obtain the greatest possible resistance over the charge of powder; if it could be made as strong as the rock itself it would be perfection.

If 12 inches of one species of tamping will afford as much resistance as 18 inches of another, the question will be, Does the former, in the application, require as much more time and expense as the operation of boring the additional 6 inches of hole? if not, it will, under most circumstances, be better in the relative proportion of that expenditure.

Where other qualities are equal, that which can be applied in the least space of time will be far preferable, particularly in such operations as sinking shafts, driving long narrow galleries or driftways, and other situations where the progress is necessarily slow.

Different materials are employed for tamping:

I. The chips and dust of the quarry itself. This is what is most commonly used, unless there be flint or other stone in it that notoriously strikes fire.

II. Sand poured in loose, or stirred up as it is poured in, to make it more compact. This is an approved material in many places, and is recommended to be very fine and dry.

III. Clay, well dried, either by exposure to the sun, or, what is more certain and more rapid, by a fire.

Wherever blasting is going on, there must be smiths' forges at work: the clay is formed by the hand into rolls of about 2 inches in diameter, and readily dried by the smiths' fires.

In the course of some experiments, clay was used that was in a state of powder, owing to its having been dried a long time previous, and was not thought so good as when applied in a state just caked enough to remain in lump.

IV. Broken brick is an approved material in some localities, as being less liable to accidents by striking fire, than chips of stone.

It is used in small pieces and dust, and is improved by being slightly moistened with water during the ramming.

Vegetable earth, or any small rubbish, is sometimes applied instead of the stone chips, when the latter are considered dangerous. Such are the simple ingredients used in tamping; that is, exclusive of the addition of any mechanical contrivance: of these, the most essential to analyse is the application of sand; since its use has been by many strongly recommended, and, if efficacious, would be most convenient, on account of the rapidity and security with which it can be applied.

In Cachin's Mémoire sur la Digne de Cherbourg, printed in 1820, (a most

interesting work as regards the construction of breakwaters,) it is thus stated in a note.

"In blasting rock at Cherbourg, the use of the needle, and well-rammed tamping, has been long abandoned.

"The priming is in the usual manner by straws, and the tamping is of very fine dry sand, poured in.

"It has been proved by long experience that the effect of the explosion is as great by this method, as by the more laborious tamping in the usual manner."

And in the Journal of the Franklin Institute (United States) for July and August, 1836, after quoting a variety of experiments on the resistance of sand to motion through tubes, made as well in France as in America, and facts regarding the bursting of musket barrels, &c. by charges of sand over the powder, the conclusion come to is, that

"Experience proves that the resistance offered by sand is quite sufficient for blasting rocks, and it is less troublesome, and more safe, than the usual mode."

It is added, that

"To ensure success, the space left above the powder should have a length of ten or twelve times as great as the diameter of the hole."

Colonel Pasley, on the contrary, asserts that sand as an ingredient for tamping was found at Chatham to be utterly valueless; but acknowledges that the opportunities there of blasting were few and on a very small scale. Many other officers of the British Engineers have been long under the same impression.

It does not appear that any of these opinions have been formed upon any more precise experiments than the sensible effect upon stones or rock with the usual charges; and as these effects are very different under circumstances that are apparently similar, and as they might vary with different proportions of the powder and ingredients used, advantage was taken of the opportunity afforded by the works carrying on at Kingstown Harbour, near Dublin, to try a few experiments that should be somewhat more definite.

The principle which it was thought would be most conclusive, was not to form a judgment by the effect produced on the rock, but to endeavour, if possible, to obtain a charge of powder that should in each case just blow out, or sensibly affect, the *tamping;* and a comparison of the charges to produce that effect would afford a strong proof of the relative value of the different systems; thus,—

If it should be shown (as will be found in the following Table of experiments) that ¼ of an ounce of powder would blow out the sand tamping which filled a hole of 1 inch diameter and 2 feet deep, while 3 ounces in a similar hole would not disturb a well-rammed clay tamping, it afforded a perfect confirmation of Colonel Pasley's statement, that the sand was good for nothing, as far as the use of it on that scale went.

The experiments detailed in the following Tables were made in granite rock, and, as far as could be judged, where it was firm, and without fissures.

The charges were of ordinary Merchants' blasting powder, procured from the contractors.

The sand was sharp or gritty, quite dry, and simply poured in over the powder, with a little wad of hay intervening. It was from the seashore, and of different qualities.

The finest was a clean running sand, fine enough nearly for an hour glass, and weighed . . . . . 65 lbs. per cube foot.

The second quality, a middling gritty sand, and weighed . . . . 93 lbs.

The third, very coarse, or rather very fine sea shingle, the particles being from the size of a pin's head to that of a pea, and weighed . . . . . . 98 lbs.

The clay had been dried at the fire of a smith's forge, and was well rammed down in the usual manner.

Experiments to try the comparative value of sand and clay for tamping.

F Sand, fine. M Sand, middling. C Sand, coarse.

Number of experiments.	Depth of hole.	Diameter of hole.	Charge of powder.		Description of tamping.	Effect and Remarks.
No.	feet.	inches.	lbs.	oz.		
1	2	1	0	2	Clay.	½ inch of top of tamping removed—rock fractured.
2	2	1	0	2	do.	Tamping remained—rock star-fracture.
3	2	1	0	2	do.	8½ inches of tamping removed—rock fractured.
4	2	1	0	2	do.	Tamping remained—rock fractured.
5	2	1	0	3	do.	Portions of tamping adhered to sides of the hole—a mass of rock blown off.
6	2	1	0	3	do.	Tamping all remained—rock fractured.
7	2	1	0	3	do.	1⅜ inch of tamping removed—rock fractured.
8	2	1	0	3	do.	Tamping remained entire—rock fractured.
9	2	1	0	4	do.	5½ inches of tamping removed—rock fractured.
10	2	1	0	4	do.	2 inches of tamping removed—rock star-fracture.
11	2	1	0	2	Sand.	Tamping entirely blown out—rock uninjured.
12	2	1	0	1	do.	do. do.
13	2	1	0	1	do.	do. do.
14	2	1	0	0¾	do.	do. do.
15	2	1	0	0½	do.	do. do.
16	2	1	0	0¼	do.	do. do. This was repeated three times with the same effect. N.B. By the ordinary miners' rule of allowing ⅓ depth of hole for the charge, one of 2 feet deep by 1 inch diameter would require 3½ ounces.
17	4	1½	0	6	Clay.	1 ft. 8 in. of top of tamping removed—rock fractured.
18	4	1½	0	6	Sand.	Tamping blown clean out—no fracture. N.B. In hole 4 feet by 1½ inch, ⅓ of depth will contain 15 ounces of powder.
19	6	2	0	8	M Sand.	Tamping blown out—no fracture.
20	6	2	0	8	C Sand.	4 feet 7 inches of tamping blown out, below which was a hard crust of about 4 inches thick, and in the cavity below there remained 8 or 9 inches of the sand, mixed with burnt powder—no fracture in the rock.
21	6	2	0	10	Clay.	Tamping unmoved—rock uninjured.
22	6	2	0	10	Sand.	1 inch of top of sand removed—rock fractured.
23	6	2	0	10	M Sand.	Tamping blown out—no fracture in rock.
24	6	2	0	12	Clay.	2 inches of tamping removed—rock fractured.
25	6	2	0	12	Sand.	2 feet 4 inches of sand removed.
26	6	2	0	12	M Sand.	Tamping all blown out—no fracture.
27	6	2	0	14	Clay.	1 inch removed—rock fractured.
28	6	2	0	14	Sand.	7 inches removed—rock fractured.
29	6	2	1	0	Clay.	Tamping unmoved—rock fractured thoroughly.
30	6	2	1	0	Sand.	Tamping blown out—rock fractured thoroughly.
31	6	2	1	0	C Sand.	Tamping unmoved—rock lifted—the explosion probably escaped through the joints.
32	6	2	1	4	C Sand.	Tamping blown out—rock star-fractured.
33	6	2	1	8	C Sand.	Blown out—rock slightly cracked.
34	6	2	1	8	C Sand.	Tamping blown out—rock shaken, joints opened.
35	6	2	1	8	C Sand.	do. —no fracture.

Experiments to try the comparative value of sand and clay for tamping.

F Sand, fine. M Sand, middling. C Sand, coarse.

Number of experiments.	Depth of hole.	Diameter of hole.	Charge of powder.	Description of tamping.	Effect and Remarks.
No.	feet.	inches.	lbs. oz.		
36	6	2	1 8	C Sand.	4 feet 1 inch blown out, then 3 inches of loose sand, and below that a hard crust—no fracture of rock.
37	6	2	1 8	Clay.	Tamping unmoved—rock cracked. N.B. In hole 6 feet by 2 inches, ⅓ of depth will contain 2 pounds 8 ounces of powder.
38	9	2	0 6	M Sand.	7 feet 10 inches blown out } no fracture in rock.
39	9	2	0 8	M Sand.	8 feet 6½ inches do.
40	9	2	0 8	C Sand.	7 feet 4 inches do.
41	9	2	0 10	C Sand.	7 feet 1½ inch do.
42	9	2	0 12	M Sand.	Tamping blown out—no fracture.
43	9	2	0 12	C Sand.	7 feet blown out—no fracture—a hard substance 1 foot 3 inches above bottom of hole; then a cavity of 2 or 3 inches, and under it sand mixed with burnt powder; the crust required considerable labour to pierce with a 2-inch churn jumper, worked by 2 men.
44	9	2	0 14	C Sand.	6 feet 10½ inches blown out—no fracture—similar hard crust to preceding No.
45	9	2	3 0	Clay.	Tamping unmoved—rock very slightly cracked. N.B. ⅓ of hole 9 feet by 2 inches will contain 3¾ lbs. of powder.
46	9	2½	1 0	C Sand.	3 feet 11 inches blown out—no fracture—similar hard crust found.
47	9	2½	1 0	M Sand.	Blown out, except a small crust of about ½ inch thick.
48	9	2½	1 8	C Sand.	5 feet 3 inches blown out—rock cracked.
49	9	2½	2 0	C Sand.	Tamping unmoved.
50	9	2½	3 0	C Sand.	Tamping unmoved—the explosion found vent by a side joint near the charge—making an extensive fracture.
51	9	2½	3 0	Clay.	Tamping unmoved—rock fractured.
52	9	2½	3 8	C Sand.	5 feet 10 inches blown out—no fracture.
53	9	2½	4 0	Clay.	Tamping unmoved—rock fractured.
54	9	2½	4 0	C Sand.	3 feet 2 inches blown out—no fracture—the hard crust 5 feet 7 inches from top of hole was some inches thick.
55	9	2½	4 8	C Sand.	Blown all out—rock slightly fractured.
56	9	2½	5 0	C Sand.	Blown all out—rock fractured.
57	9	2½	5 0	Clay.	Tamping unmoved—rock fractured.
58	9	2½	6 0	Clay.	Tamping unmoved—rock shaken—explosion escaped through side joints. N.B. ⅓ of depth of hole 9 feet by 2½ inches would contain 5 lbs. 14 oz., or nearly 6 lbs. of powder.

In the same paper of the Franklin Institute above referred to, it is stated that the sand was sometimes poured in loose, and sometimes carefully *packed.*

The packing was performed by means of a small sharp stick, which was worked up and down as the sand was slowly poured in.

It is stated, that

" This method was found to be the best, and is the one always used at Fort Adams, in charging drill holes for sand blasting.

" Sand that was packed presented a much greater resistance than that which was poured in loose."

In order to try the value of thus packing the sand, it was ascertained how much was added to the mass by this mode of condensation; for this purpose we used a tin tube of 24 inches long by $2\frac{1}{8}$ inches diameter at mouth.
$2\frac{1}{16}$ do. do. at bottom.

When filled with the different qualities of sand, the weights were respectively—

	Fine.	Middling.	Coarse.
	oz.	oz.	oz.
Poured in loose	65	76	80
Packed by process above described	74	$83\frac{1}{2}$	84

Many trials in blasting were made with tamping of sand thus packed.

In holes 2 feet deep by 1 inch diameter, each of the three qualities of sand was tried with an $\frac{1}{2}$ ounce and a $\frac{1}{4}$ ounce charge, and in the whole of them the sand was all blown out.

Experiments on tamping with packed sand.

F Sand, fine. M Sand, middling. C Sand, Coarse.

Number of experiments.	Depth of hole.	Diameter of hole.	Charge of powder.	Description of tamping.	Effect and Remarks.
No.	feet.	inches.	lbs. oz.		
59	4	1½	0 7	C Sand.	Tamping blown out.
60	4	1½	0 7	C do.	Tamping remained—rock fractured.
61	4	1½	0 6	M do.	2 feet 6¼ inches removed—rock fractured.
62	4	1½	0 6	M do.	1 foot 5¼ inches removed—rock fractured.
63	4	1½	0 6	C do.	Tamping blown out—but a slight crust adhered to the sides of the hole.
64	4	1½	0 5	M do.	Tamping blown out.
65	4	1½	0 5	C do.	Tamping removed—except a hard crust about 12 inches above bottom of hole.
66	4	1½	0 5	C do.	do. do.
67	4	1½	0 4	M do.	3 inches of tamping only remained.
68	4	1½	0 4	F do.	Tamping blown quite out.
69	6	2	0 7	F do.	In all these, the tamping blown out.
70	—	—	0 6	—	
71	—	—	0 5	—	
72	—	—	0 4	—	
73	—	—	0 3	—	All blown out but 1½ inch.
74	—	—	0 12	M do.	In all these, the tamping blown out.
75	—	—	0 11	—	
76	—	—	0 10	—	
77	—	—	0 9	—	
78	—	—	0 8	—	
79	—	—	0 7	—	
80	—	—	0 10	M do.	About 1 foot of sand remained—rock fractured.
81	—	—	1 0	C do.	Tried twice—in both cases the tamping blown out.
82	—	—	0 15	—	Blown out, except a hard crust 17½ inches from bottom.
83	—	—	0 15	—	2 feet removed—a hard crust, took 2 men 40 minutes to bore through.
84	—	—	0 14	—	16 inches remained—hard crust formed.
85	—	—	0 13	—	Blown out, all but hard crust.
86	—	—	0 13	—	3 feet 6½ inches blown out—hard crust 12 or 14 inches thick, bored through with much labour.
87	—	—	0 12	—	5 feet 4½ inches blown out.

The quality of the sand has not been always noted in these or the former trials; but all three kinds were employed. The very fine, contrary to the received opinion that it is the best, universally failed: the very coarse, in the larger explosions, was, for a few inches in thickness, generally vitrified or cemented together into a very hard crust. On trial with an acid, it was found that there were some particles of limestone mixed with this sand, the sudden burning of which might perhaps have assisted in producing this effect.

In all the descriptions of sand, indeed, this cementing process took place, at times, more or less, and all of them contained particles of lime.

These last experiments were made at a different period from the former trials of sand, and probably with some variety in the quality of the powder and material, which must account for the apparent inferiority of the packed sand; whereas the *packed* must be the best, although in too small a degree to remedy the inherent defects in any tamping of sand.

In fact it is impossible to reduce these kinds of experiments to any very close results *in detail*, although by numerous trials we may come to *general results* that may be well relied on.

The conclusion come to from all these experiments, notwithstanding some discrepancies that will be observed, is, that sand of any description, and however applied, is, when used by itself for small blasts, perfectly worthless, and quite inferior to clay tamping for larger explosions, at least so far as for holes 9 feet deep by 2½ inches in diameter.

The cause of the sand tamping not presenting the same resistance to the explosion of powder in a blasting hole, that it does to the mechanical pressure through tubes, is, no doubt, that the explosion penetrates among the particles, and loosens and separates them, instead of wedging them together as when pressed. The same action will be observed in a subsequent part to produce an extraordinary effect on sand or other loose material when used with iron cones.

No examination was made in any of these or preceding experiments of the quality of the powder, excepting those expressly for that object. It was in all cases the ordinary Merchants' blasting powder; nor was any account taken of weather, or other such circumstances, as might cause discrepancies in trials made at different periods.

The only other materials for tamping, requiring much notice, are

Broken brick, and

Broken stone, or quarry rubbish.

I. *Broken brick* is a good material for tamping, and gives considerable resistance, though not so much as clay: vide Nos. 116, 117, 118, in Table. It will not strike fire with iron, and it is to be procured in most situations.

II. *Broken stone* is of two qualities. Some quarrymen are in the habit of using a rotten kind of stone that is found in most stone countries; not being brittle, it rams into a very firm mass, and is not subject to strike fire; but being *stone* at all, gives an opportunity for careless workmen to apply the harder

quality instead, or, at any rate, to mix pieces of the latter with it, by which the operation is subject to the contingencies of the use of the hard material.

The ordinary material used for tamping is the broken stone and rubbish of the quarry itself, unless notoriously subject to strike fire.

This, by experiment with the blue limestone or granite of the neighbourhood of Dublin, was found to be inferior to clay as a resisting medium. Vide experiment, No. 119.

It is also more liable to cut the safety fuse, or to derange the needle hole; but, above all, it is never, in any rock, entirely free from some danger of giving fire, and causing accidents: this is quite enough to occasion it to be rejected wherever it is possible to procure a substitute.

Experiments with tamping of clay, broken brick, and broken stone.

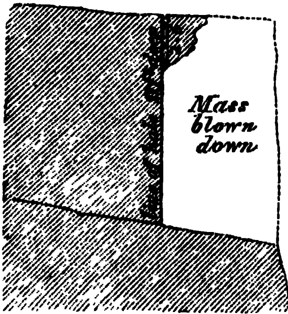
No. of experiments.	Holes.			Charge and description of powder.	Tamping.	Results and Observations.
	Depth.		Diam^r.			
No.	ft.	in.	inches.			
88	3	0	2	2 oz. Contractors.	Clay from 4 to 16 inches.	All blown out.
89	3	0	2	,,	Do. 17 inches.	A small quantity left.
90	3	0	2	,,	Do. 18 inches.	All blown out.
91	2	0	2	,,	Do. 19 inches.	7 inches of tamping removed.
92	2	0	2	2 oz. Gov^t.	Do. 19 inches.	7½ inches removed.
93	3	0	2	2 oz. Cont^{rs}.	Do. 20 inches.	5½ inches removed.
94	2	0	2	2 oz. Gov^t.	Do. 20 inches.	8½ inches removed.
95	3	0	2	2 oz. Cont^{rs}.	Do. 24 inches.	3 inches removed.
96	2	2	2	2 oz. Gov^t.	Do. 24 inches.	6 inches removed.
97	2	10	2	3 oz. Cont^{rs}.	Do. 2 ft. 8¾ in.	Tamping undisturbed—rock well cracked—line of least resistance 19 inches in a favourable position, near a salient angle.
98	3	2	2	3 oz. Gov^t.	Do. 3 ft. 1¾ in.	Tamping blown out—rock, to all appearance, not affected—line of least resistance 2 feet, in an unfavourable position, near a re-entering angle.[10]
99	4	1½	2	2½ oz. Cont^{rs}.	Do. 4 feet.	16 inches removed—the clay in this case was very dry, and in powder, and was considered to be less efficient than when caked.
100	3	0	2	4 oz. Cont^{rs}.	Do. 24 inches.	Tamping not disturbed—rock lifted.
101	1	7	2	1 oz. Cont^{rs}.	Do. 10 inches.	All blown out.
102	1	2½	2	1 oz. Cont^{rs}.	Do. 12 inches.	About 3 inches of top blown out, and a considerable portion round fuse hole.
103 to 105	3	0	1	2 oz. Cont^{rs}.	Do. 5 & 6 in.	All blown out.

[10] The effect on the tamping in this experiment (No. 98) is so different from all the others, with even superior charges, (vide Nos. 100, and 114 to 122,) that there was probably some misapprehension in preparing or recording the experiment.

Experiments with tamping of clay, broken brick, and broken stone.

No. of experiments.	Holes. Depth.	Holes. Diamr.	Charge and description of powder.	Tamping.	Results and Observations.
No.	ft. in.	inches.			
106	3 0	1	2 oz. Contrs.	Clay, 7 inches.	1½ inch removed.
107	3 0	1	2 oz. Govt.	Do. 7 inches.	All blown out—tried twice.
108	2 9½	1	2 oz. Govt.	Do. 8 inches.	¾ inch removed—rock slightly affected.
109	3 1	1	2 oz. Govt.	Do. 8 inches.	2½ inches removed.
110	4 0	3	2 oz. Contrs.	Do. 14 inches.	All blown out.
111	3 9½	3	2 oz. Contrs.	Do. 18 inches.	All blown out.
112	2 0	3	2 oz. Contrs.	Do. 20 inches.	Very little removed, except on side of fuse hole.
113	3 10½	3	2 oz. Contrs.	Do. 22 inches.	13 inches removed.
114	4 0¼	3	4 oz. Contrs.	Do. 26 inches.	17½ inches removed.
115	4 0¼	3	4 oz. Contrs.	Do. 30 inches.	22 inches removed.
116	3 2	2	4 oz. Contrs.	Do. 24 inches.	Tamping undisturbed — rock slightly cracked.
117	3 2	2	4 oz. Contrs.	Do. 22 inches.	3 inches of top of tamping removed—the remainder undisturbed.
118	3 2	2	4 oz. Contrs.	Do. 21 inches.	4 inches of tamping removed—rock burst.
119	3 2	2	4 oz. Contrs.	Do. 20 inches.	1 inch removed—rock burst.
120	2 0	2	4 oz. Contrs.	Do. 18 inches.	6 inches removed—rock burst.
121	2 0	3	4 oz. Contrs.	Do. 20 inches.	Rock burst—enlarged upper part of fuse hole.
122	2 0	3	4 oz. Contrs.	Do. 18 inches.	8 inches removed—rock burst.
123	16 0	4	35 lbs. Contractors.	Do. 9 feet.	The charge occupied 7 feet—the rock was separated across the hole, at the outer end of which 4 inches of the tamping was found firmly adhering to the side of the half hole in the solid rock.
124	7 2	2	2 lbs. 8 oz. Contrs.	Do. 5 ft. 2 in.	The powder occupied 2 feet—the rock was separated so as to cut the hole longitudinally in two—the tamping was found adhering firmly to 15 inches of the upper end of the half hole.
125	11 0	3	19 lbs. 12 oz. Contrs.	Do. 4 feet.	The powder occupied 7 feet out of 11—the face of the rock was blown down along the line of the hole, excepting the upper 2 feet six inches which remained, and in which the tamping continued firmly fixed after the explosion. Fig. 13, p. 69.
126	2 0	2	2 oz. Contrs.	Broken brick, quite dry, 18 inches.	All blown out.
127	2 0	2	2 oz. Contrs.	Do. 23 inches.	All blown out.
128	2 0	2	2 oz. Govt.	Broken brick, damped, 23 inches.	All blown out, except a slight incrustation on sides near the bottom.
129	2 0	2	2 oz. Contrs.	Broken granite stone, 23 inches.	All blown out—the stone was nearly in a state of disintegration.

Fig. 13.



But few trials were made with broken brick; the object was merely to confirm the opinion that it possessed no decided advantage, in point of resistance, over clay: if any thing, it is believed to be somewhat inferior, and requires a little moisture, which is a slight disadvantage; and it is more liable to have particles of stone, or hard material that might strike fire, mixed up with it.

The broken stone was tried once or twice besides the instance recorded, and in all showed an inferiority to the clay; the use of it being always attended with more or less of danger, it was not thought advisable even to *experiment* much with it.

It will be perceived that in holes of 2 inches diameter, 2 ounces of powder will blow out about 18 inches of clay, and not more.

In holes of 1 inch diameter, 2 ounces will not blow out above 7 inches.

In holes of 3 inches diameter, 2 ounces will not blow out above 19 or 20 inches.

This comparison, however, is not quite conclusive enough to found a theory on, as the position of so small a quantity as 2 ounces spread on the surface of a 3-inch hole gives it a disadvantage, whereas in a 1-inch hole it lies very compact.

Increase of charges does not produce the increased effect upon good tamping that might be expected. It has been shown (Nos. 90, 91, Table of Experiments,) that in a 2-inch hole 2 ounces of powder will just blow out 18 inches of the tamping; in No. 100, and from 116 to 122, it will be found that 4 ounces, that is, double the charge, had scarcely, if at all, more effect, so far as can be judged under the different circumstances.

When however the rock is opened by the explosion, the effect on a tamping of clay or other tough material is greatly reduced; see Nos. 123 and 124, and particularly No. 125, for a remarkable instance of this; also Nos. 97 and 98, for the difference in effect on the tamping caused by the rock yielding, or not, to the explosion. It would appear that the action upon the rock in opening it is much more rapid than on the tamping; even where the rock is separated across the line of the hole itself, the tamping is usually found adhering to one or both sides.

This is a very favourable circumstance in blasting.

It would be interesting to follow up the experiments of the effect of varying charges, with varying depths and diameters, upon one uniform description of clay or other good tamping; it would seem probable that after a certain point, which may be perhaps about 24 inches in a 2-feet hole, the charges to remove increasing depths of such tamping must be increased in a much greater proportion even than as the cubes of those depths: it is very difficult however to make such experiments, on account of the bursting of the rock with increasing charges, by which the effect on the tamping is reduced; it could only be done by holes in re-entering angles, *very closely* bound by projecting masses.

After having tried the value of the ordinary modes of tamping with broken stone, sand, brick, and clay, it becomes worthy of consideration whether additional resistance might not be obtained by some mechanical application of a different nature, tending to save time, labour, and chances of accident.

Any such contrivance, to be practically of general service, must be very simple in construction and application, and obtained at an expense not disproportionate to the advantages gained by its use.

The one that naturally suggests itself is some kind of plug or wedge, fixed in the loaded hole in a manner to increase the resistance.

If such a plug could be contrived to give with sand, or loose small broken stone, or quarry rubbish, equal resistance to the same depth of good clay tamping, a very great advantage would be obtained in rapidity[11] of the tamping, and in security from accidents.

Many trials were made for this purpose.

The first was with an iron plug of 2 or 3 inches long, and very slightly coned, the larger end being of somewhat greater diameter than the hole.

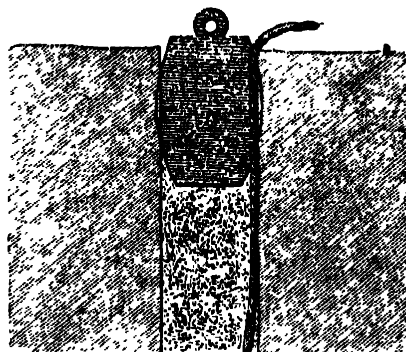
It is well known that such plugs, when driven into a hole in rock, and not having perhaps half an inch of contact, will raise from the ground the weight of many tons, showing a degree of tenacity that it was expected would be very powerful against the explosion from within; but when tried over the sand, although evidently affording much increased opposition, they were still in all cases driven out with sharp explosions, by smaller quantities of powder than would have removed good clay tamping.

[11] Substantial tamping is usually executed at the rate of from 6 to 12 inches per minute; 9 inches per minute may therefore be calculated upon as a medium for holes of almost any size.

Plugs of wood were tried with a similar result.

Iron plugs, of a form *slightly* curved in a barrel shape, and about 3 inches long, were also tried, and with better effect: when tightly driven in to the top of the hole they took firm hold, and over loose sand, when properly fitted, appeared to give more resistance than equal depths of clay (vide Nos. 130, 131, 132 of Tables); they had a groove along the side for the fuse to pass through (fig. 14), and a strong eye to which a string could be fastened with some object attached, to enable it to be seen and found if the plug was forced into the air.

FIG. 14.

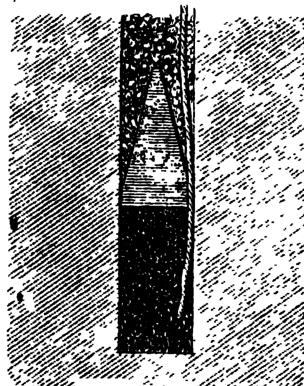


A few of them were made for 2-inch holes, that is, varying in diameter from a little less to a little more than 2 inches; so that from the set it was easy by trial to find one that would fit with a proper degree of tightness.

The objections to the use of such plugs would be,—expense; occasional losses; when blown out, some danger of falling on the by-standers; a degree of difficulty in removing them when not blown out, or the rock cracked precisely across the mouth of the hole; and want of simplicity by requiring an additional implement;—in this case, too, there is the chance of the workmen carelessly applying such as would not fit well, by which they would be rendered of little or no service.

Pins formed of cylindrical pieces of iron, 6 inches long, whereof two sides were taken off, each of them of the thickness at top of about a quarter of the diameter of the cylinder, and tapering to nothing at the bottom, so as to form two wedges, were then tried over sand at the upper edge of the hole; and although the pin was driven up against these wedges, and much effect produced, still they were not equal to the clay.

FIG. 15.



A cone placed immediately on the charge of powder, and filled over with stone broken to pieces of about ½ inch cube (fig. 15), it was considered would give very powerful effects. Such a cone at the end of a rod of iron, and having only 16 inches of broken stone over it, at Chatham, where the idea

originated, was proved, to support a weight of 16 tons. A similar trial was made subsequently at Kingstown, and it supported a weight of 10 tons without showing any signs of yielding, and even with fine sand, instead of stone, over it; and although the base of the cone was only 1¾ inch in a hole of 2⅜ inches in diameter, it sustained the same weight perfectly.

Still, notwithstanding this great power when opposed to the gradual application of a force from above, it was found to give way to the explosion of the powder from below (see Nos. 133 to 145).

It would seem that the explosion penetrates round the sides of the cones, however small the windage (and they cannot be made to fit very tight, on account of the irregular size and shape of the holes), and by the fuse hole, and acts directly on the broken stone or sand above, so as to prevent its operating as a wedge.

Some of the objections to the barrel-shaped plugs apply to these cones also: it would be attended with great labour to extract them if not disengaged by the explosion; and it would be very difficult to apply them in holes horizontal, or nearly so, unless they were very shallow.

The last contrivance tried, and which, as far as it has gone, has given a greater degree of resistance than any other mode of tamping, has been the application of iron cones, with long iron arrows applied as wedges (fig. 16).

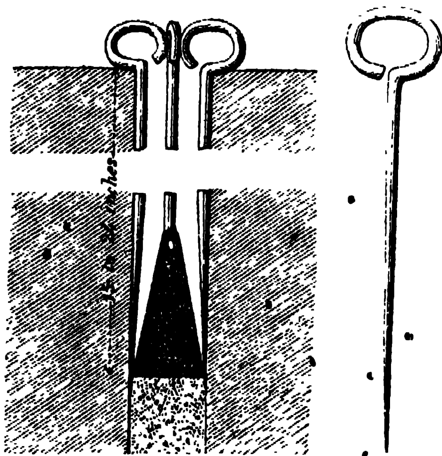
The cones may be from 3 to 6 inches long, with a groove for the fuse, and an eye at the top;

The arrows, from 21 inches to 2 feet 6 inches long, made of ½-inch round iron, with a long fine point at one end, and turned to a handle at the other.

The arrows are proposed to be of this shape, as perhaps the cheapest that could be made.

These cones were inserted at from 6 inches to 2 feet below the edge of the hole: for their effects, see Nos. 146 to 163 of the following Tables.

Fig. 16.



The arrows should not be less than ⅜ inch thick (see No. 152), nor more

than $\frac{5}{8}$; nor fewer in number than 3 for a 2-inch hole, or 5 for a 3-inch (see Nos. 152, and 161, 162).

The cone is let down over the sand, clay, or rubbish, and the arrows are fixed to their position by a slight blow or two with a hammer or stone.

The objections to this implement are in some respects similar to the others; namely, expense, chance of occasional losses when blown out, or of falling on people's heads; almost impossibility, frequently, of removing them when not blown out, without breaking open the rock; and want of simplicity in requiring so many additional implements.

The wear and tear of the arrows would be considerable, as they are usually thoroughly flattened near their lower end, and sometimes broken by the explosion.

One remarkable circumstance occurred repeatedly in the trials with these cones and arrows.

With sand laid over the charge of powder, and *under* the cones, the latter were firmly wedged, while the sand (sometimes in considerable quantity) was blown out entirely, or nearly so, by the small opening between the base of the cone and the side of the hole, the cones not being particularly loose, or more so than was necessary to go down freely, (see Nos. 146, 149, experiments.)

Even clay to the depth of 6 inches was removed in the same manner from *under* the cone (No. 156).

Broken stone could not escape in a similar way, but the explosions through it were observed also to find a vent round the sides of the cones.

From 8 to 12 inches of clay tamping over the sand prevented this effect.

Experiments on tamping with different kinds of iron plugs or cones.

No. of experiments.	Holes. Depth.	Holes. Diameter.	Charge and description of powder.	Description of tamping.	Results and Observations.
No.	ft. in.	in.			
130	2 0	2	2 oz. Contrs.	20 inches of sand, then an iron plug of barrel shape, 3 inches long, driven in very firm.	Plug not stirred.
131	6 0	2	1 lb. 8 oz. Contractors.	Fine sand over charge to within 3 in. of top, then barrel-shaped plug.	Plug unmoved—rock cracked—3 ft. 4 in. of sand remained in hole.
132	6 0	2	1 lb. 12 oz. Contractors.	Tamping as in preceding trial.	Plug and tamping unmoved—rock thoroughly rent.

Experiments on tamping with different kinds of iron plugs or cones.

No. of experiments.	Holes. Depth.		Holes. Diameter	Charge and description of powder.	Description of tamping.	Results and Observations.
No.	ft.	in.	in.			
133	2	0	2	1 oz. Cont[rs].	Iron cone 6 in. long by 1⅞ in. diameter at base, over charge, then sand to top.	All blown out.
134	6	0	2	2 oz. Gov[t].	Iron cone 6 inches, then fine sand to top.	4 ft. 5 in. of sand removed, cone and 1 ft. of sand remained.
135	3	0	2	2 oz. Cont[rs].	4 in. fine sand, then iron cone, then sand to top.	All blown out.
136	5	1½	2	2 oz. Gov[t].	2 in. of sand, then iron cone 2½ inches long, with sand to top.	Blew all the sand out—the cone remained at the bottom of the hole.
137	2	0	2	2 oz. Gov[t].	Iron cone 3¾ inches, then gravel to top.	All blown out.
138	6	0	2	2 oz. Gov[t].	Iron cone 6 inches, then gravel to top.	2 ft. 9 in. of gravel blown out—the cone and remainder of the gravel remained.
139	2	0	2	2 oz. Gov[t].	Iron cone 3¾ inches, then broken granite stone (about ½ in. cube) to top.	All blown out.
140	2	0	2	2 oz. Gov[t].	Iron cone 2½ inches, then broken stone, as above, to top.	All blown out.
141	2	0	2	1 oz. Cont[rs].	Iron cone 6 inches, then broken limestone to top.	All blown out.
142	3	0	2	2 oz. Cont[rs].	4 in. broken limestone, then iron cone, with broken stone to top.	All blown out.
143	2	0	2	1 oz. Gov[t].	5 in. clay, then iron cone 6 in. long, 1 1/16 in. diameter at base, then sand to top.	All blown out.
144	2	0	2	2 oz. Cont[rs].	8 inches clay, then iron cone 5½ in., then broken granite to top.	All blown out except about 2 inches of clay at bottom.
145	3	0	2	2 oz. Cont[rs].	14 in. sand, then 4 in. clay, then iron cone 4 in., with broken stone (about 18 inches) to top.	The cone, broken stone, and some sand blown out, as well as a small portion of the clay.
146	3	0	2	2 oz. Cont[rs].	2 feet fine sand, then iron cone wedged with 3 arrows ⅜ inch thick, then sand to top.	All the sand blown out from *below* as well as above the cone, except about 2 inches, which was partly vitrified; the cone and arrows remained, and more firmly wedged.
147	3	0	2	2 oz. Cont[rs].	Precisely as the preceding, but with broken stone instead of stand.	The stone above the cone blown out, that below remained; the cone more firmly wedged.
148	3	0	2	4 oz. Gov[t].	2 ft. 2 in. broken limestone, with fine sand intermixed, then cone and 3 arrows, then stone and sand to top.	Stone and sand over the cone blown out; the cone more firmly wedged. It was conceived that the intermixture of fine sand with the broken stone might prevent the explosion escaping round the side of the cone; but it did not.

Experiments on tamping with different kinds of iron plugs or cones.

No. of experiments.	Holes. Depth.	Diameter	Charge and description of powder.	Description of tamping.	Results and Observations.
No.	ft. in.	in.			
149	2 0	2	2 oz. Gov^{t}.	12 inches fine sand, then iron cone 4 inches, with 3 arrows.	The sand all blown out, except about an inch; cone and arrows firmly fixed.
150	2 0	2	2 oz. Cont^{rs}.	14 inches sand, middling quality, then 4 inches clay, then iron cone, with 3 arrows, and sand to top.	Upper sand blown out—cone wedged very firm.
151	2 0	2	4 oz. Gov^{t}.	15 inches sand, then 4 in. clay, then cone, with 3 arrows, and sand to top. N.B. Only 3 inches for cone and arrows.	Upper sand blown out—cone remained fixed. The clay (4 inches) under the cone was found to be detached from the side of the rock for about half its circumference, the middle of which part was where the fuse had passed.
152	2 0	2	2 oz. Gov^{t}.	14 inches fine gravel, then cone 4 inches, with 4 arrows only ¼ inch thick.	All blown out—the arrows in this experiment were too thin to wedge firmly.
153	2 0	2	2 oz. Gov^{t}.	12 inches of small broken stone and its dust, then cone 4 inches, and 3 arrows.	All blown out—this instance of failure could not be accounted for—must have been occasioned by some accidental circumstance—vide next experiment.
154	1 3	2	2 oz. Cont^{rs}.	5 inches broken stone, then cone 5½ inches, and 3 arrows.	Cone raised a little and firmly wedged—the explosion passed round the cone, being observed to escape at the top.
155	2 0	2	2 oz. Gov^{t}.	6 inches clay, then cone 6 inches, and 3 arrows.	All blown out—one of the arrows found greatly bent.
156	2 0	2	2 oz. Cont^{rs}.	6 inches clay, then cone 5½ inches, and 3 arrows.	Cone not stirred—nearly all the clay was found to be blown out from *under* the cone.
157	2 0	2	2 oz. Gov^{t}.	8 inches clay, then cone 6 inches, with 3 arrows.	Cone and arrows thoroughly wedged—rock uninjured.
158	2 0	2	2 oz. Gov^{t}.	10 inches clay, then cone 6 inches, and 3 arrows.	Cone and arrows thoroughly wedged—rock well cracked.
159	1 2½	2	2 oz. Cont^{rs}.	4 inches clay, then cone, with 3 arrows.	Cone and arrows thoroughly wedged.
160	3 0	2	1 lb. Cont^{rs}.	12 inches clay, then cone 4 inches, with 3 arrows.	Rock thoroughly split, and large mass lifted—the clay remained, but opened by splitting of rock—the cone found inside the hole, the arrows thrown out.
161	2 0	3	4 oz. Cont^{rs}.	6 inches clay, then cone 6 inches, and 4 arrows.	All blown out—broken parts of the arrows found flattened, and side of the hole marked with the arrows—the *number* of arrows evidently insufficient for the 3-inch hole.
162	2 0	3	4 oz. Cont^{rs}.	8 inches clay, then cone, with 4 arrows.	All blown out—arrows found much bent and flattened.
163	2 0	3	4 oz. Cont^{rs}.	13 inches clay, then cone, with 5 arrows.	The cone well wedged—about 2 inches of clay removed.

In all cases the powder was poured in by a copper tube to the bottom of the hole, and a very thin covering of one or two folds of paper was the only wadding used.

The rock was not affected, so far as could be perceived, unless where otherwise mentioned.

Clay, and broken brick tamping, were in all cases firmly rammed down.

Sand and gravel in all cases poured in loose.

Broken stone, when employed by itself, was well rammed; and when used with any kind of plugs or cones, it was poured in loose.

Where *portions* of the tamping were removed, it was considered to have been occasioned by the escape of the explosion up the fuse hole, or round the cones, and not by the general concussion.

The conclusions which I think may be reasonably drawn from the foregoing experiments and observations on tamping, are,

1. That clay dried to a certain extent is, all things considered, the best material that can be used for tamping.

2. That broken brick, tempered with a little moisture during the operation, is the next best material.

3. That some kinds of rotten stone are as good as either, but that it is not so easy to be sure of always having the proper kind, and the use of it is very likely to lead to an occasional substitution or mixture of stone of other quality, such as is decidedly objectionable.

4. That sand, or any other matter poured in loose, is entirely inefficient.

5. That the stone-dust and chippings of the excavation itself, (excepting the rotten kind above mentioned,) afford less resistance than clay, and being always more or less attended with risk of accidents by untimely explosion, should never be employed.

6. That of the mechanical contrivances by means of plugs or wedges, the most effective of those referred to are, the cone with arrows, and the barrel-shaped plug; both of which, particularly the former, give a great increase of resistance; but that all such contrivances, leading to increased expense, requiring extra arrangements, and some attention to a proper application, such as cannot always be depended upon, are none of them applicable to ordinary purposes, but might be very useful under circumstances where every blast is under great difficulties, or attended with much expense; for instance,

under water, or in carrying on shafts, galleries, &c., through very hard rocks; in such cases the additional cost and labour of employing these means would perhaps be well repaid by the improved effect of each explosion.

In the case of blasting in shafts and confined driftways, where the openings made by the explosion *must* necessarily be across the line of the hole, one great difficulty, namely, that of disengaging the cone or plug after the firing, does not occur.

In very confined situations, like the bottom of small shafts, where the greatest possible effect is required from the shallowest holes; the effects from deep holes being counteracted by the infinite resistance of the contiguous masses, these means of increasing the resistance of the tamping might be very useful.

The comparative strength of different kinds of tamping will vary in a small degree in different places; that which is most commonly used, will, in each locality, give relatively, no doubt, better effects; thus where broken brick or broken stone are commonly employed, they will perhaps on trial be found to give somewhat better results, as compared with clay, than are noted in these Tables, which were drawn up where the clay was in habitual use, and the others were only tried for experiment; but it is apprehended, that although they may vary in degree, in no case would the difference be so great as to alter the relative *order* in which they stand.

TUNNELLING.

By far the most difficult, expensive, and dilatory blasting operations, are those connected with sinking shafts, and driving galleries in rock.

The disadvantages under which such work proceeds, arise from

1. Want of space in which to work to most effect.
2. Want of light.
3. Want of pure air.
4. Penetration of water into the works, sometimes in large quantities.
5. The necessity for securing the parts excavated, on every side, from loose fragments, or other portions that might give way.
6. The inconvenient communication for men and implements, for removing the material, &c., to and from the work during the operation.

These peculiarities are such as to justify and even to require the most perfect

arrangements and contrivances to be made use of; some that might be considered, for ordinary blasting, as leading to unnecessary refinement and cost.

Where the undertaking is of considerable extent, the *length of time* it is to take in the execution may be a matter of great importance: should it be that which must *necessarily* occupy the longest time in the construction of a railway, canal, or other great work, it may be well worth while to pay an extra cost, and what, under common circumstances, might appear to be an extravagant outlay, in order to open the establishment earlier to the receipt of some large revenue; for instance, it would undoubtedly be good policy to lay out any given sum *extra*, to expedite the opening of such an undertaking by so much time, as would lead to a larger return of clear profit: it is upon this principle that in the great railways, night-work by large bodies of men, and other subjects of extra outlay, are sometimes resorted to; and that embankments, cuttings, &c., are hurried on in a manner to render much subsequent expense necessary before they become perfectly substantial.

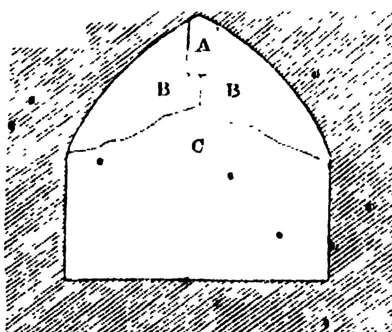
A tunnel thus accelerated may be much more costly in construction than otherwise.

The easiest tunnels or galleries to open, are those that can be worked from the ends, without requiring any shaft; and more particularly those worked on an ascending inclination, by which any water met with has a natural drainage away.

Sometimes it may be so well circumstanced, as to rise from both ends, and have a summit in the interior.

The disadvantage of blasting in a re-entering angle, surrounded on all sides by great resistance, has been adverted to: this would be the case nearly through the whole progress of a tunnel, if the face were all to be taken out together, and therefore the following, it is conceived, would be a better order of proceeding, and has partially been acted upon in some instances.

Fig. 17



Commence by a gallery or driftway A. (fig. 17), at the apex of the roof,[12] as small as can conveniently be worked in; viz.

[12] The driftway is more usually carried along the *floor* of the gallery, to give a supposed advantage for drainage; but, as I think, erroneously.

about 6 feet high by 3 feet wide. This will be carried on necessarily in the most disadvantageous way for the effect of the powder, as previously explained.

The next portion to work out will be B B; and in that, some advantage will be obtained from the first opening A, to apply the powder to more effect.

The great mass C will be then removed almost as favourably as in an open quarry, having a face towards that part of the same portion C, that has been previously removed, to which the lines of least resistance can be directed.

Thus A will throughout be kept well in advance of B, and B in advance of C.

It is probable that each, without checking the progress of the part preceding, may be made to keep pace with it; and if so, the whole tunnel may be worked out in nearly the same time as would be required for a driftway.

The advantage of beginning at the roof is,

1. The scaffolding and ladders for working from, become unnecessary.

2. The roof or arch is easily got at, and made sound and secure in the first instance.

3. The drainage is facilitated as the work proceeds, as will be explained.

In tunnels of very great length, the operation would be far too long by working them only from one or even from both ends: it becomes necessary then to sink shafts to intermediate points, from the bottom of which the tunnel is carried on in each direction until the whole shall be connected.

This of course will add very greatly to the difficulty and expense:

1. By the additional labour of excavating the shafts.

2. By the necessity for passing all the workmen, implements, tools, and the materials from the excavation, up or down the shaft, as the case may be.

3. By the limited space below, particularly as subject to the interruptions occasioned by the explosions, from which it is more difficult to obtain refuge.

4. By the probable necessity for increased artificial means of ventilation.

5. And principally, by the machinery and labour requisite to keep each distinct shaft, and the galleries connected with it, free from water.

The expenses will be increased in proportion to the number of shafts; and the number of shafts will be regulated by the time to which the execution of the tunnel is limited.

Thus, if the nature of the rock and other circumstances are such, that the

engineer cannot be sure of penetrating faster at each head of driving the gallery, than 3 yards per week, if the tunnel is to be 2 miles long, and the period for its being opened three years from the commencement; on these data 468 yards would be the amount that would be opened during three years in each head of working, requiring consequently between 7 and 8 heads for the whole, or 3 shafts, and the two ends. This however would be to suppose that the work commences at once from the *bottom* of each shaft: the time necessary for sinking the shafts however must be considered, which will consequently increase the necessary number of them.

Where the rate of penetrating shall be slower, and the period for the operation the same, the number of shafts must be increased, and *vice versâ* where it shall be the contrary: and this rate at which the work can be carried on, is extremely difficult to be ascertained previously, with any certainty; it is one in which any engineer may err.

Should the calculation be a close one, any contingency that may interrupt the work at any one point will stop the opening of the whole, for there is no possibility of accelerating in any great degree such work at any one head; and, on the contrary, if measures be taken to make it *much more* than sure, it can only be by increasing the number of shafts and heads of working, which will greatly increase the expense, and perhaps, as the event may show, be unnecessary.

A good record of the actual result of working tunnels, with a minute detail of all particulars, is very much wanted as a guide for future operations.

Many circumstances will have influence upon the dimensions to be given to tunnels; if for a railway,—the width of the locomotives and carriages, the height of the former, &c.

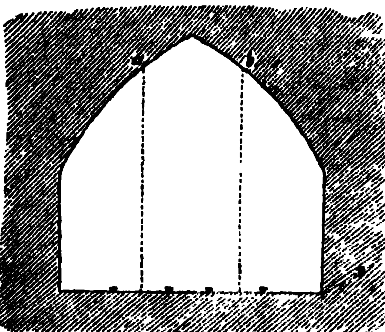
Certain dimensions may be deemed fixed: for a railway, for instance, the height of the vertical side walls, suppose 10 feet; the space between the two tracks, and between each of them and the walls, suppose 16 feet in all; besides the width of the track of this space it might be better to diminish that in the middle, and to increase those on the sides, suppose 4 feet for the first, and 6 feet for each of the others, because

1. The side spaces would be more useful for gas or other pipes, or for lamps, or for drains, or for tools or materials during repairs.

2. It is the readiest and most natural position for any person to seek for refuge, should an engine or carriage pass while he may be in the tunnel.

The roof should be as flat as the rock will admit to be secure, provided there be sufficient height for the engine up to *a b*, (fig. 18,) over each trackway.

Fig. 18.



Some rocks will bear being cut to an almost straight horizontal roof; this will be particularly the case where the strata are vertical, or nearly so: others require to be high and pointed; when even that form shall be insufficient, the very troublesome and costly expedient of lining with brick or masonry must be resorted to.

It has been sometimes proposed to construct a double gallery for a tunnel; one for the traffic in one direction, and the other for that in the opposite: the assumed advantages are,

1. That a small roof may be more easily secured than a larger one.

2. That one line can be opened first, and the second worked out by degrees, and at leisure, without interrupting the traffic in the first.

3. That the cross traffic cannot at any time interfere, and that persons who may be accidentally in a gallery while an engine or carriage is about to pass, will find secure refuge in the other, or in the connecting passages.

4. That the subsequent repairs, &c. will be quite safe from any interference with the traffic, which would then be confined to the line not under repair.

It is not the object here to discuss any principles not connected with blasting rock; therefore in loose soil requiring to be lined, the double tunnel may be advantageous, or may be otherwise.

In chalk, a material that is easily worked and shaped, and in rocks like it, and in which a large roof may be of doubtful stability, while a small one might be considered secure, this system would be most applicable; but I should think it objectionable in hard rocks requiring to be blasted.

A single tunnel of 28 feet wide will afford as much useful accommodation as two of 18 feet wide each.

Suppose the width of trackway to be 6 feet; then, in either case, there would be a space of 6 feet between each trackway and the wall: but as it is proposed above to allow but 4 feet between the two trackways, it may be considered a more fair comparison to calculate each of the double galleries as only 16 feet wide.

3. The danger of any thing, even small articles, falling down upon them.

4. The difficulty of applying any holes for blasting, but such as are vertical, or nearly so.

5. The immediate vicinity of the receptacle for the drainage water, from which it will be almost impossible to keep clear.

It will be found more advantageous probably to sink shafts rather long and narrow (the length crossing the direction of the tunnel at right angles), than circular or square; for instance, 16 feet by 9 feet may be better dimensions to give a shaft than 12 feet each way, provided always that the width is *ample* for working the buckets up and down. By this arrangement it will be easier to apply transverse bearers across the top for machinery; the space for the workmen will be more convenient; the pipes for drawing off the water for ventilation, &c. will be more out of the way at one end, while the buckets for drawing men and materials, &c. up and down, may be at the other.

The upper surface edge of each shaft must be thoroughly lined, and secured from the possibility of any thing falling down; the buckets and windlass of perfect description and arrangement to prevent such accidents, or the striking against each other in meeting, &c.

It is in blasting at the bottom of shafts that the shields described in another part might, it is conceived, be more usefully applied than in any other situation. The holes will be vertical, the blasts small, the shield always close at hand, and the great labour and loss of time saved of removing the workmen to the top of the shaft at each blast.

When the shaft is sunk to the depth of the *driftway* at the *roof* of the galleries, those driftways may be at once commenced to save time; and the remainder of the shaft sunk while the gallery work is going on.

EFFECTS OF STRATA.

In stratified rocks, the direction of the strata in tunnelling will be of much importance.

The most favourable would be vertical, and at right angles with the direction of the line of tunnel, because when the drift A (fig. 21) is carried to sufficient extent, the holes for the subsequent blasts can be bored down the joints, and the explosion made to act in the most favourable manner.

The same principle may be adopted where the strata may be inclined

Fig. 21.—(Longitudinal Section).

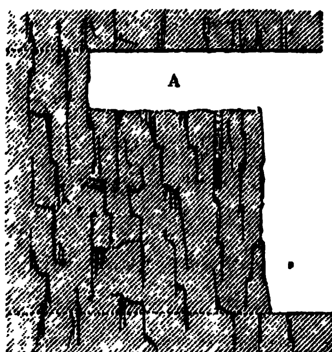
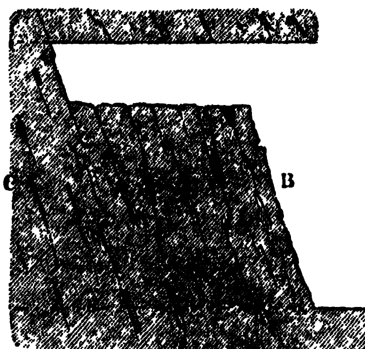


Fig. 22.—(Longitudinal Section).

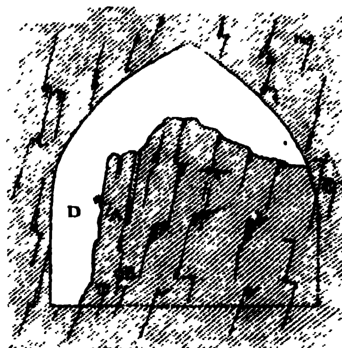


upwards from the miners, as at B (fig. 22), but it will be more difficult to work with advantage from the other end of the gallery C; as, to follow the same principle, the rock will be always overhanging the workmen.

If the strata be in horizontal beds, it will be worked upon by horizontal boring after the roof is entirely cleared out.

A most unfavourable direction is when the work is proceeding in the same line with vertical strata, which will consequently always present their edges in front.

Fig. 23.



In that case an opening should be carried down from top to bottom, either at one side at D (fig. 23), or in any other part, and then the holes bored down the strata as at A, or horizontally as at B; the whole roof, however, and opening D, will be worked to much disadvantage.

DRAINAGE.

An adequate drain will be necessary through the whole length of any tunnel.

A very favourable inclination for a gallery, as respects drainage, would be about 16 feet in a mile (1 in 330).[14]

[14] Whether for ordinary road or railway, the incline in a tunnel should be easy; as it would be peculiarly inconvenient in that particular part of a line to incur the risk of a stoppage in ascending, or of an accident in descending.

The drain will be larger or smaller according to the quantity of water which it may have to discharge, but at 1 in 330 the fall will be sufficiently considerable to render a very large drain probably unnecessary.

In working the *ascending* galleries, either from the end or from a shaft, it will be quite easy to proceed so that there shall be always a natural drainage, at every period, to the receptacles from whence it will run off, or be pumped out, as the case may be.

But in each *descending* gallery some little arrangement must be made to assist it.

When the descending meets the ascending gallery, the whole of the drainage will be carried off by the latter; till then, the following arrangement will be better than carrying pipes to the end of the gallery, as must be done if the inclination be steep.

Suppose the descending gallery to be 440 yards in length before it is to meet the other; this, at 16 feet to a mile, will give a perpendicular difference of level of 4 feet: as the gallery will be from 24 to 30 feet high, it is manifest that the far greater portion may have a regular natural drainage out, the same as an ascending gallery; but by sinking a small well-hole at the bottom of the shaft, of 5 or 6 feet deep, from whence the pump may draw the water out, a drain may be cut to it from the very end of such descending gallery, as it progresses, that will carry off the water naturally from its very floor.

That drain will form part of the regular longitudinal drain that must be made at all events, and the only additional labour will be in excavating the well in each shaft, which also might at any rate be desirable.

It has been stated that 16 feet in a mile would be a very favourable inclination in this respect (and perhaps in others for a railway through a tunnel): should the slope be steeper, a deeper receptacle and drain would be necessary, until it came to the point that might render it preferable to apply pipes all along the gallery instead.

When the tunnel or gallery is to be horizontal, as it must be for a canal, the drainage will be as described for the *descending* gallery.

In deep sinkings, drainage is sometimes effected, or rather more usually *assisted*, by means of Artesian wells or bore-holes sunk from lower levels of the surface ground, down to the lines of strata that shall *descend* from the works. Where the joints shall not be too close, and the distance not too great, the water will be drawn from the works by this self-acting drainage down to

the level of the top of the Artesian bore-hole; or, *practically*, to nearly that level.

VENTILATION.

The difficulty of working galleries to any extent under ground is occasionally very great, for want of ventilation, or from the presence of foul air.

The remedies are, either to force fresh air to the end of the work, or to draw the foul air off from thence, when the fresh air will rush into the vacuum: the latter is esteemed to be the more easily effected.

In either case there must be an air-tight tube from the fresh air to the part where the workmen are engaged; and the great difficulty must be to establish such a tube perfectly firm and perfectly air-tight.

In operations on a small scale, such as military miners are engaged in, a small and light tubing is used, and the air forced in by a pair of smith's bellows, or others of about equal power; but to work a gallery of some hundred yards long from the bottom of deep shafts, will require tubing more substantial and of larger dimensions, with a continued force applied for exhausting the foul air; or fresh air has frequently been introduced by a fan-wheel.

In a recent number of the Annales des Ponts et Chaussées of France, there is an account of a simple contrivance which enabled the working of a shaft of 5 feet diameter, and 220 feet deep, to be continued after it had been interrupted by the constant collection of carbonic acid gas; all the ordinary measures by bellows, &c. having proved quite ineffectual.

A large tub A (fig. 24) was firmly placed on balks on a level with the top of the shaft, and filled with water to the level G, G.

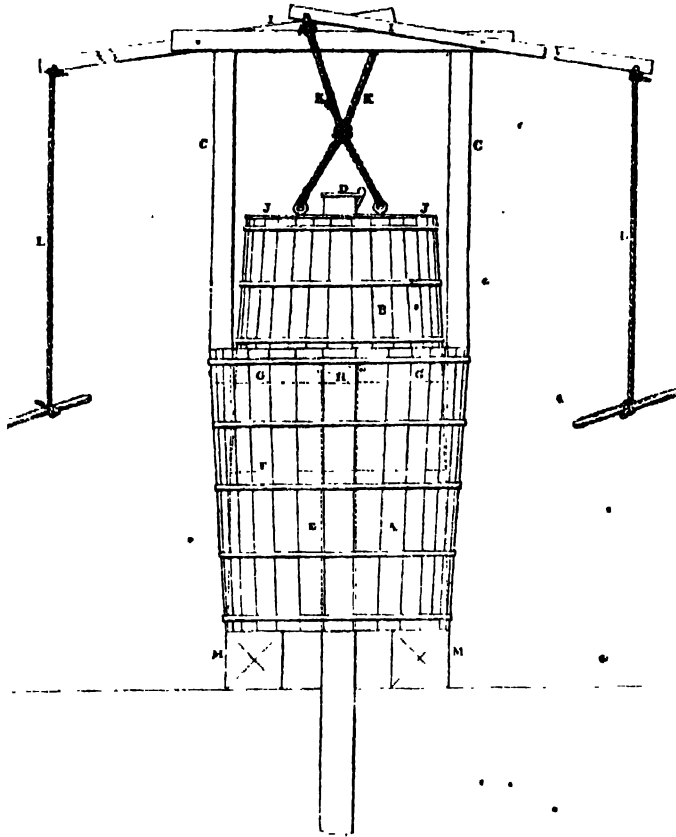
An air-tight pipe from the bottom of the shaft was brought through the tub A, and had its upper edge a very few inches above the water; it had a valve H on the top.

A smaller tub B, reversed, was suspended within A, by the cords K, K, which were made fast to the ends of the levers I, I.

B had a very short pipe at top, with a valve D.

The tub B being allowed to descend by its own weight, the air within it was expelled through the opening D; when again raised by pulling the handles attached to the ropes L, L, the air was drawn up through the opening H, from

Fig. 24.



the end of the descending tube, and by continuing this reciprocating action, a circulation was created at the very bottom of the shaft.

No dimensions are given; but it is conjectured that the lower tub A would be about 4 feet by 3 feet 6 inches, and the upper one B, about 3 feet by 3 feet.

It was found capable of drawing off 4 cubic yards of air per minute.

No additional men were employed to work it; those at the top of the shaft, who got out the materials from the excavation, were only required to work this pump for about 5 minutes every hour, to keep the air perfectly good at the bottom.

It is in fact an air-exhausting pump of large power and simple construction: if found useful, and required for regular service, it might no doubt be improved, and made more compact, portable, and easy of application.

Instead of using a pump or manual labour for drawing the air from the ends of galleries, the upper ends of the tubes are sometimes made to communicate

with a fire kept constantly burning, to which the tubes furnish exclusively the requisite air.

Improved ventilation is said to be obtained by double galleries or driftways, with occasional air-holes connecting them.

The advantage in this respect can hardly be equal to the cost of carrying on the double opening, if not necessary for other objects.

COST.

No kind of work can be more variable in its cost than tunnelling, or driving galleries: so much will depend upon the quality of the rock, the depth at which the gallery is under ground, the facility of communication by more or less of confined galleries, shafts, &c. to and from the actual work,—the amount of necessary ventilation, and the quantity of water to be drawn off,—that the expense may vary from 2*s.* to £2, and much more, per cube yard.

Where the rate is very heavy, it will probably be good economy to adopt the most refined improvements that will forward that portion of the operation which peculiarly leads to the extra expense

The following is the result of the cost of working out the road tunnel of Drenodrohm, between Kenmare and Glengariff, during 1836 and 1837, in the county of Kerry under many favourable circumstances.

The piercing of this tunnel, which was 582 feet in length, through the summit ridge of the mountain, saved an ascent, of which the perpendicular height was from 60 to 80 feet, which, reduced from a constant rise of 1000 feet on each side, was of much value.

The rock was stratified, varying in character from a granular to a compact silicious, and to a common clay slate, intersected by veins of quartz. It was all hard, some of it exceedingly so.

The strata in one direction were nearly vertical to the horizon, excepting occasional veins of a few feet in thickness, which were more inclined; and in the other direction, nearly perpendicular to the line of the tunnel.

The rise in the tunnel was from both ends, and at the rate of 1 in 100, forming a summit in the middle, which was consequently nearly 3 feet higher than the entrance.

The passage, as commenced, was meant to be 18 feet wide and 18 feet high; but subsequently, to save expense, the width of the roof or chord of

the arch was reduced to from 15 to 17 feet, and the part below the arch to 12 feet.

The arch stood perfectly without any support, although cut *very* flat, and with a rise or versed sine of only 6 feet.

The cost of the different portions was as follows:

The roof or arch was first cut out, and contained sectional areas at different parts of about 96 and 90 feet, comprising an excavation of about 2012 cube yards in the aggregate, and cost £655 16*s.* 8*d.*, being at the rate of about 6*s.* 6*d.* per cube yard.

The body of the gallery under the arch contained sectional areas of about 204 and 144 feet, comprising an excavation of about 3493 cube yards, and cost £599 1*s.* 11*d.*, being at the rate of about 3*s.* 5¼*d.* per cube yard.

A small shaft, 6 feet by 4 feet, was opened to the depth of 33 feet, containing about 29⅓ cube yards, and cost £32 2*s.* 10*d.*, being at the rate of £1 1*s.* 10¾*d* per cube yard.[15]

The average cost of tunnel alone per cube yard	4*s.* 6½*d.*
„ „ „ of tunnel and shaft	4*s.* 8*d.*

The material from the excavation was deposited in hollows near the entrance at each end.

The total cost of tunnel and shaft £1287 1*s.* 5*d.*; exclusive of some miners' cottages built, and a few such contingencies.

HEADS OF EXPENSE.

		£.	s.	d.
Labour .	Miners and labourers	620	9	8
„ . . .	Smiths (including coals) . . .	73	3	3
Iron . .	13,109 lbs. at 1·7*d* per lb. . .	92	16	6
Steel . .	321 lbs. at 1*s.* per lb. . . .	16	1	0
Gunpowder	7,946 lbs. at 1*s.* per lb.	397	6	0
Safety fuse	1,745 coils, of 8 yards each, at 1*s.*	87	5	0
		£1287	1	5

At the railway tunnel at Liverpool, the excavation of the rock is stated to have cost 4*s* per cube yard; the material was a sand stone, and, as it required

[15] This shaft proved eventually of little or no use, and had better have been omitted.

to be lined nearly throughout with brick wall and arch, was not probably very hard.

It would form a most useful guide to engineers, if record were kept, and made public, of all the particulars of the actual experience in tunnelling and driving galleries, and sinking shafts: it might be kept without difficulty, and be made to afford very useful checks on the works during the operation.

J. F. B.

VI.—*Passage of the Indus by the Bengal portion of the Army of the Indus. By Lieut.* H. M. Durand, *Bengal Engineers.*

In the middle of the year 1838, Herat being besieged by the Persians, the advance of a British force into Afghanistan was decided upon; and as the relief of the above fortress was the primary object at the time that the expedition was planned, and therefore determined the line upon which operations were to be conducted, His Excellency the Commander-in-Chief, Sir Henry Fane, early intimated to Captain G. Thomson, appointed Chief Engineer to the force, the route which the army was destined to take, and called his attention to the first difficulty which would present itself—the passage of the Indus.

Upon the 12th of October, 1838, His Excellency called for a report upon the manner in which Captain Thomson proposed to facilitate the speedy transit of the troops, more especially of the cavalry, artillery, baggage, and commissariat cattle of the army, across the river, and signified that the neighbourhood of Bukkur would probably be the point of passage.

In consequence of this communication, rough estimates were framed of the means which would be required to throw a bridge of boats across the Indus; and as no accurate information as to the size of boats was to be procured, the estimates were varied to suit whichever of two supposed sizes the boats should be found to approach. At the same time the project submitted was, that if Bukkur were the point selected, and a sufficiency of boats were procurable, both branches of the river should be bridged in such a manner as to admit of the crossing of infantry, cavalry, light field-batteries of artillery, and camels of the army; but that for the transport of the battering guns, a strong boat-raft should be put together, and pier heads for embarkation and disembarkation be formed on each bank of the river.

Subsequently to the dispatch of the report and estimates, information of a more accurate nature was furnished. A copy of Lieutenant Wood's Memoir on the Indus near to Bukkur, and some account of the nature of the boats, which

it was hoped would be collected in great numbers, was obtained. In consequence of this additional information, and of the decision of Government that preliminary measures should be entered upon, a modified estimate was drawn out, and forwarded to Lieutenant Cunningham, Engineers' Assistant, political agent at Ferozepoor, who was at the same time instructed to purchase 500 Devdar timbers, and render such other assistance as it might be in his power to afford.

On the 24th October, 1838, the detachment of sappers and miners destined for field-service, consisting of two companies, quitted the vicinity of Delhi, and, accompanied by the engineer park, reached Kurnaul, the point of assembly for the infantry of the force, on the 30th. At the latter place orders were received on the 6th November respecting the preparations to be made in conjunction with the political and other authorities, and directions given that an engineer officer should, with all practical expedition, move to Ferozepoor. In obedience to these instructions, Captain Thomson arrived at the latter place on the 22nd November, and immediately instituted inquiries into the progress made towards the collection of the materials ordered, and as to the number of boats available for the transport of the sappers, and of the engineer park, by water to Bukkur. Lieutenant Wood, of the Indian navy, was found in charge of such boats as had been brought together, and he had been suddenly ordered, in consequence of an approaching interview between the Governor General and Maharajah Runjeet Sing, to throw a bridge of boats across the Sutledge. In order to effect this, Lieutenant Wood was directed by Lieutenant Cunningham to make use of such timbers and planking as the latter had collected, at Captain Thomson's requisition, for the bridge to be constructed at Bukkur. In compliance with his instructions, Lieutenant Wood had thrown a bridge, 347 feet wide, composed of 25 boats, across the Sutledge, and had employed in its platform all the material that Lieutenant Cunningham had collected, viz.

75 balks, 8″ × 6″ scantling,
3602 superficial feet of planking,
4000 feet of 3-inch rope.

Finding this to be the amount of the preparations made, and that the remainder of the boats at Ferozepoor, in all 105, had been allotted in about equal numbers to Shah Shoojah's contingent, to the sick of the army, and to the commissariat department, Captain Thomson, upon the arrival of Sir Henry

Fane, proposed that the engineers, and sappers and miners, should at once march down the left bank of the Sutledge and Indus, so as to arrive at Bukkur some time before the body of the force; and that a detachment of 50 sappers under Lieutenant Sturt, of the Engineers, should be left to dismantle the bridge across the Sutledge, when no longer required by the Governor General. Lieutenant Sturt having done this, was then to drop down the river in charge of part of the boats of Lieutenant Wood's bridge, and was to bring with him the above-specified materials collected by Lieutenant Cunningham, and the rafts of timbers which Captain Thomson, on his arrival at Ferozepoor, caused to be bought, and which, very fortunately for the success of the contemplated operation, though they had to be brought from a distance, reached Ferozepoor before the departure of Lieutenant Sturt.

Captain Thomson's proposal was made on the supposition that a large number of boats had actually been collected at or near to Bukkur, and that these, together with a quantity of timbers ordered by Colonel Wade, political agent, to be floated from Mooltan, would be available immediately on the arrival of the detachment, and that the work to be undertaken would thus be far advanced by the time that the army was assembled at the point of passage. The Commander-in-Chief, on the 30th November, ordered that the detachment should proceed as recommended, starting from Ferozepoor on the 2nd December.

When within two marches of Buhawulpore a letter was received, showing that, from causes which it is not here necessary to explain, the aid that had been expected from the collection of boats at Bukkur would be almost entirely wanting. Captain Thomson nevertheless considered that the orders he had received were imperative, and that he should do his utmost to carry them into effect,—that there was still time, if exertions were made, to collect boats and materials,—and pointed out how necessary the measure was, when reference was had to the number of troops, camp followers, baggage, and commissariat cattle, which must cross the Indus.

On the 2nd January, when within nine marches of Bukkur, Captain Sanders, of the Engineers, was sent forward by forced marches to join Major Leech, assistant political agent at Shekarpoor, with the view of ascertaining the exact state of the preparations made by the latter officer, to whom Sir A. Burnes had, about the 18th December, intrusted the duty of co-operating with the engineer department. Captain Sanders, upon reaching Shekarpoor, reported that not

more than five boats had been collected, and that the preparations were such as indicated that nothing beyond the construction of a few rafts had been held in view. In company with Major Leech, he then proceeded to Bukkur, and with the cordial aid of the above-mentioned officer, Captain Sanders succeeded in collecting a few more boats.

The detachment reached the Indus at Gote Amil on the 10th January, 1839, and was occupied during the 11th and 12th in crossing the river. This, from the breadth of the river (1100 yards), the nature of the ferry, the secondary size and the small number of the boats, proved a very tedious operation, and was not effected without the loss of several camels and of one boat sunk.

Lieutenant Sturt, with his flotilla of ten boats, reached Gote Amil on the same day as the detachment.

On the 12th January Captain Thomson proceeded to Sukkur, in order to examine and fix upon the best site for the proposed bridge; and on the 13th, as soon as intimation was received from Major Leech that his negotiations with the Kyepoor Ameer had been successful, the detachment of sappers and miners marched to Sukkur, and encamped on the right bank of the Indus, within a musket-shot distance from the fort of Bukkur. Lieutenant Sturt, who had succeeded in bringing down the boats and timber-rafts in safety to Gote Amil from Ferozepoor, had a couple of rafts broken up between Gote Amil and Sukkur. The accident occurred at some violent eddies opposite to the village of Rahooja, where the river, having a sudden fall down a rapid, set with violence against the right bank, and formed eddies from which it was difficult to extricate unmanageable timber-rafts: of the two broken up, most of the timbers and planks were subsequently recovered.

By reference to the accompanying plan it will be observed that the Indus Plate VIII. immediately above Sukkur flows in a direction from north-west to south-east, with an average breadth of 700 yards. In order to break through the range of limestone rocks on which Sukkur, Bukkur, and Roree are situated, the river then makes a sudden turn, and courses in a south-westerly direction, forcing its way through two channels, of which the eastern is the most considerable. The channel in question at the narrowest point, that is, at the part between the north-east angle of the fort and the town of Roree, has a breadth of only about 570 feet; but the stream there flows over the ledge of rocks with great rapidity, and immediately enlarges to a breadth of 1050 feet at the south-western end of the fort. The western channel is of much smaller dimensions, averaging in

breadth only 300 feet, and possesses a more gentle current than the main channel. The space between these two branches of the river assumes a triangular form, having a length of 2600 feet, and a breadth of 1500 feet, and is almost wholly occupied by the fort.

The point selected by Captain Thomson for the site of the bridge was the south-western extremity of the fort, this being the *narrowest available* part of the river,—a circumstance of primary importance, from the great uncertainty which existed as to the number of boats which might be forthcoming.

The main channel was indeed much narrower at the north-eastern corner of the fort; but in addition to the fact that at the time of the arrival of the detachment at Sukkur the cession of the fort was not agreed to, and that so much jealousy was evinced that Captain Thomson was cautioned by the political agent against giving the slightest umbrage to the local authorities of the Ameer, there were the following considerations, which rendered the narrowest part of the east channel not the most eligible locality for the proposed work. The river here, forced to flow through so confined an opening, runs with great violence, and from the features of the neighbouring ground there was no doubt but that the bed of the channel would prove to be bare rock, upon which it could scarcely be hoped that the rough substitutes for anchors, to which recourse must be had, would be able to hold effectually.

The approach to the east end of the bridge on the Roree side would also have been difficult; and the landing on the island of Bukkur, and the passage round the north end of the fort, between the inner and outer walls, would, even if allowed, have been very inconvenient.

The site shown in the plate was therefore chosen as being the one which, under all the circumstances of the case, presented the greatest advantages. The western channel was there 400 feet, and the eastern 1100 feet, in breadth.

ENGINEERS' MEANS AVAILABLE.

Captain Thomson, Chief Engineer, Army of the Indus.
,, Sanders, Bengal Engineers.
Lieutenant Anderson do.
,, Durand do.
,, Sturt do.
,, M'Leod do.
,, Pigou do.
,, Broadfoot do.

The 2nd and 3rd Companies of Bengal Sappers and Miners, consisting of 14 European sergeants and 270 Sepoys.

PARK ESTABLISHMENT.

31 Clashers.
13 Carpenters.
12 Smiths.

WORKMEN HIRED DURING THE WORK.

29 Carpenters.
96 Sawyers.
41 Rope-makers.

JOURNAL.

14th January.—The bridging of the western channel commenced with the preliminary operation of forming a pier head or abutment for the first boat. This was rendered necessary by the nature of the bank, which, near the water, was a quicksand of such a kind that an eleven-foot pile, when driven down, did not resist pressure with the hand. In order to connect the first boat with the higher and firmer part of the bank, a row of date-trees, 26 feet long, were laid end on to the stream, and others, 18 feet long, laid above and across the former or lower tier, so as to form a species of platform. Piles were driven both in front and in rear of the cross layers, and the whole well lashed together with rope. Tamarisk brushwood was then filled into the intervals between the date-trees, and the causeway completed subsequently with fascines. The carpenters were set to work making anchors; during the day two were made, loaded with stones, and had their cables bent on; the wood-work of twenty more was ready, and six in preparation. A rope-walk was established, and the rope-makers commenced the manufacture of moorige cables. The sappers were employed in unloading the boats brought down by Lieutenant Sturt, and in hauling up the timbers from the rafts. As fast as the boats were cleared, their crews unrigged them.

15th January.—Sixty men employed in cutting brushwood, and sixty in making fascines; the remainder employed on the bridge. Six anchors were laid down, and six boats put into position. The boats used in the formation of this bridge were of the secondary size, that is, about 30 feet in extreme length, and from 11 to 13 feet in breadth: their sterns rise to a high point, but their bows are low: only the stern and a small portion of the fore part of these boats are decked, the remainder is open, but

[1] This Journal is taken principally from the Journal of the Chief Engineer.

braced across by two or three stout balks which connect the gunwales. Balks were laid upon five of the boats; thirty anchors were ready by the evening, of which twenty-one were loaded and had their cables bent on. The crews of the ten large boats brought down by Lieutenant Sturt were employed in making cables, and throughout the continuation of the work, the crews of any boats obtained, either assisted at the rope-walk, or in carrying materials and rendering such assistance as was in their power. Most of the beams and the planks which had been lost by the breaking of the two rafts in the eddies at Rahooja were brought in during the forenoon, and the finders recompensed.

16th January.—The alignment of the boats corrected, balks placed, and carpenters set to work nailing the planks down and sawing off the ends; a pier head commenced on the opposite bank of the western channel, the date-trees being carried over from the right bank where they were cut down. The number of anchors loaded, with cables attached, was 50; the sawyers commenced cutting balks out of the timbers brought from Ferozepoor; of those promised by Major Wade, not one even made its appearance.

17th January.—Eighty-seven anchors loaded, with cables complete: half the rope-makers were discharged, and the making of anchors stopped *pro tempore.* The carpenters at work fastening down the planking on the bridge, and putting stanchions between the balks and bottoms of the boats, in order to strengthen the latter.

18th January.—Bridge over the western channel, consisting of nineteen boats, finished, having occupied, inclusive of time required for pier heads, four days in construction. The sappers employed in making fascines, in forming a pier head of date-trees for the right bank abutment of the bridge across the main or eastern channel, and in preparing a wharf, or pier head, on the right bank below the bridge, for the disembarkation of the battering guns.

19th January.—Commenced two pier heads on the Roree side of the river, one for the left bank abutment of the main bridge, the other for the embarkation of the battering guns. Most of the men cutting brushwood and making fascines, the latter being of great use in forming causeways wherever the approaches to the bridges are likely to work into quicksand. The banks and flats of sand proved very treacherous, presenting a firm appearance until tried by the passing and re-passing of the working parties, after which they frequently of a sudden worked up into regular quicksands. Two large strong zoraks were put together with a platform of stout beams and thick date-tree planking, to form a raft for the heavy guns. The zorak is a boat admirably adapted to the construction of military bridges; in length they vary from 40 to 60 feet, in breadth of beam from 12 to 15 feet, at the centre they are about 2′ 6″ deep, but the gunwales rise towards the stern; not however so much as they, comparatively speaking, do in the second class of boats before described, nor do they in the zorak come to a point both fore and aft; for the gunwales are nearly parallel to each other, both bow and stern being

thus square; the body of the boat has no deck, but is braced by strong beams connecting the gunwales: the stern and bow are decked.

20th January.—Intimation having been received that the boats allotted to the sick of the army, and to the commissariat department, would, on their arrival at Roree, be cleared out and made over to the engineer department, the prospect of obtaining a sufficiency of boats for bridging the eastern channel became nearly certain. The ten zoraks, or large boats, hitherto reserved in case that a ferry was all that could be established, were to-day anchored and aligned as the commencement of the main bridge. For these, one anchor a-piece on the up-stream side, and a stern anchor to every third boat, was found sufficient. Stern anchors were here requisite, in consequence of a fluctuating backwater which acted on a portion of the ten boats.

21st January.—Four more boats having been found and secured, were placed in line. The balks were laid, and 120 feet of planking nailed down. The width given to the roadway or platform was 10 feet, that having been deemed sufficient for all purposes of safety, at the same time that it precluded the likelihood of any danger to the structure from the crowding together in a heap of men or cattle.

22nd January.—The planking of 280 running feet completed, and anchors carried out and laid by means of the third or smallest class of boats; these anchors were for the zoraks which had arrived with the sick. Twenty-one sets of sawyers (four men to a set) at work; ninety balks and sixty planks sawn out during the last four days.

23rd January.—The boats which brought the sick having been cleared out and unrigged, eleven were placed in line and divided off to proper bays; but a strong shift in the current, with a boat running foul of the end of the bridge, sprung the dividers, and disordered the adjustment of the whole eleven boats. This was a warning that the placing of boats in position ought to be regulated by the rate at which the superstructure or platform of the bridge could be executed. Two anchors a-head and one a-stern were requisite for the above portion of the work.

24th January.—The more speedy progress of the platform being urgently required, and the fir planks not being ready in any quantity, split date-trees were laid down; they covered about 220 feet of the bridge, making nearly 500 feet of platform completed. The work had now reached the strength of the stream, which was both deep and very rapid, being rather more than 5 feet per second; the anchoring of the boats became a matter of difficulty, three anchors a-head and one a-stern being now necessary. The boats were towed up the left bank to some distance above the bridge, and then pushing off into the current, endeavoured so to drop their anchors as to be able to fall into line clear of the boats already in position. In the course of the day one boat let go its three anchors foul of those of a boat which had preceded it: with the view of rectifying the error, an attempt was made to warp up stream on the cables, so as to enable the upper boat to sheer off with the current, and drop into the interval between the lower boat and the end of the bridge; but the result was, that all six anchors tripped, and the two

boats, in spite of the number of anchors out, were carried about two miles down the river.

25th January.—It was now evident, that, having reached the strength of the stream, the bottom was bare rock, so that there was little or no hold for the flukes of the anchors: the weight of the latter was that upon which the stability of the bridge must for the future be dependent. The size of the anchors and the loading of stone was therefore increased, and an experiment made with one weighing about 10 cwt., which was found to hold the small boat which took it out. The number of boats in line was now twenty-nine, and the length of platform completed about 550 feet.

26th January.—Twelve large anchors made. They were formed of two pieces of strong curved green timber, from 5 to 6 feet long, with four thin straight sticks, 6 feet long, passed through the flukes at about 30 inches apart from each other. Stones, weighing about 10 cwt., were then loaded, and the cables bent on with two pieces of strong rope passing from under the flukes and up to the cable. As these anchors, from their weight and form, could not be carried, they were loaded on the boats from which they were to be cast; their pyramidal shape rendered it easy to cant them off over the side of the boat from the low deck at the bows. Twenty-six sets of sawyers at work, and the crews busy in making 6-inch moorige grass cables.

27th January.—The work at a stand from want of boats; there are now thirty in line from the west bank, four anchored a-head as working boats, and two for the opening which is to be on the left bank; that is, thirty-six in all, being ten brought by Lieutenant Sturt, six discovered and secured in the neighbourhood of Roree, and twenty received from the detachment of sick. The river commenced rising yesterday, and continued to do so during the night; the rise amounted to 17 inches. The rapidity of the current was much increased, and the strain on the whole structure great. During the night the platform opened in two places, which were however easily put to rights in the morning. But the oscillation in level of the water across the stream caused much trouble during the day by swaying the bridge off and against the western pier head. Had the work been completed, and the connexion between bank and bank established, there would have been much less straining; but in the exposed and unfinished state of the bridge, the end in the stream having nothing against which to abut, the whole structure was swayed in and out with every transverse oscillation of the flood. The water had risen 2 feet before night. Sir Henry Fane examined the progress of the work.

28th January.—The river rose about 6 inches since yesterday. A small boat, which acted as a buoy to the cables of three anchors, laid in readiness for the next large boat to be brought into line, was carried under water by the strength of the current; the two men in her swam to the small island below Bukkur, and were saved. Besides this accident, two of the anchors at the head of the bridge lost their hold; one was cut away, but the other got entangled among the cables and could not be got rid of. No progress, from want of boats.

29th January.—The river ceased to rise, the cables were relieved from several trees that had been floated down by the flood, and were pressing the cables under the boats. No progress made, from want of boats.

30th January.—Some of the commissariat boats having arrived, were emptied and sent down; two of them, instead of dropping down the left bank with the towing-line out, rowed down; one fortunately passed clear, but the other struck one of the small buoy boats, broke the cable, and by the shock threw overboard and drowned the man in charge of her: this was the only casualty which occurred.

31st January.—All the boats received from the commissariat fleet were brought into line, making forty from the west bank. This was safely effected by adopting a suggestion of Lieutenant Wood, I. N., who, observing the difficulty of dropping the large unmanageable zoraks down the current from above the bridge, so as exactly to hit their proper places, and the constantly increasing risk which this manœuvre entailed upon that portion of the work finished, proposed the plan of anchoring working boats well clear of the end of the completed platform, and at considerable intervals from each other. The boats necessary for filling up these intervals were then to be brought from the right bank, and along the down-stream side of the bridge, by means of a cable passed over the sterns of the boats already in alignment. By hauling on the cable, which was gradually paid off from each boat's stern as the one to be placed in position was passing, the latter without difficulty neared its proper place at the end of the platform. A hawser was then passed from the working boat to the one to be placed in alignment, by means of which hawser, and of the cables from anchors already laid out a-head, the zorak was hauled up into position without any strain upon the part of the bridge completed. Captain Thomson adopted Lieutenant Wood's suggestion, which was found admirably adapted to the object in view. It may be observed, that the bridge was not perpendicular to the set of the stream, which, striking on the bluff left bank, was shot off at a considerable angle to the line of the bridge, and thus setting on the unfinished end rendered the continuance of the work, in the manner commenced, both difficult and hazardous. Night and day a party of sappers was constantly kept upon the bridge employed in dragging up with hooks and ropes the drift wood lying athwart the cables.

1st February.—Five more boats were brought into line, and 820 feet in length of platform completed.

2nd February.—All the boats required for the bridge (55) were secured in their proper places, and only a portion of the planking remained to be executed.

3rd February.—The bridge was completed at 2 P. M.

4th February.—The commissariat department crossed over some hundred camels.

5th February.—Four thousand camels passed over the bridge; the rate was six hundred an hour, inclusive of delays from restive and timid animals. The vibration

caused by the step of the camel started a good many nails, particularly in the date-tree portion of the platform, where, from the thickness of the date planking, the spikes had less hold of the balks. Attention was paid to keep the spikes driven down and well home.

6th February.—Some camels, which had yesterday been sent back in consequence of the danger of their excessive timidity, were to-day forced upon the bridge by their drivers, and the circumstance not discovered until too late to be remedied. One of them falling into a boat, started a plank and sunk the boat. The accident occurred at 2 P.M., and was repaired before sunset, the boat being replaced by another. The bridge was opened at 5 P.M., to pass the boats taking provisions for the army advancing down the left bank towards Hyderabad. The opening was at the second boat from the left bank, and was effected by giving the boat in question short balks, which, revolving on iron bolts passed through the boat-balks, could be lifted up when the planking was removed. By this means the space of one boat and two bays was disposable for the passage of crafts; and being near to the bank, the boats dropped down carefully with the tow-line out, and all risk was avoided.

7th February.—In consequence of the fall of the river, the boat next to the pier head on the left bank grounded, and being old and rotten, the bottom came out. The pier heads for the battering guns not having been made use of when reported ready, now became useless, owing to the fall of the river, which left them with too little water in front of them for the boat-raft.

8th February.—The bridge was repaired early in the morning. Considerable difficulty occurred in finding a place where pier heads could be construeted.

9th February.—The artillery park crossed before 3 P.M., without other accident than having several bullocks fall into the boats and water; none, however, were lost. About seventy carriages of different descriptions, and two hundred and twelve carts, passed over, dragged by bullocks. In addition to these, some commissariat bullock-carts crossed, and one of them, loaded with hand mill-stones, was the severest trial to which the structure was subjected. The successful manner in which the park crossed over without accident was attributable to the care and attention shown by Captain Day, Commissary of Ordnance, and the officers and men of the European foot artillery, who superintended the operation. An elephant, notwithstanding strict orders given to the sentries to prevent these animals from being taken over, was allowed early in the morning to cross. The progress of the new pier heads retarded in consequence of an order to spare the date-trees of a grove at hand, belonging to a Syud, who promised the Brigadier left in command at Roree that other trees should be supplied.

10th February.—Nothing crossing. The new pier head on the right bank completed, that on the left untouched, no date-trees having been brought.

11th February.—The commissariat again re-crossed part of their camels.

12th February.—The crossing and re-crossing of commissariat camels so constant that no further inquiries were made as to their numbers, or the direction in which they were to cross, but precautions taken to prevent their crossing over from both banks at the same time, and meeting on the bridge.

13th February.—Intimation given that the passage of the troops would commence on the morrow. The order to respect the Syud's grove of date-trees being cancelled, the pier head on the left bank was completed, and the heavy guns were crossed over during the day.

14th February.—The 2nd brigade, consisting of three regiments of native infantry, and Captain Abbott's battery of nine-pounders, crossed this morning with about two thousand baggage camels.

15th February.—The 1st brigade of infantry, with about two thousand five hundred camels, crossed without accident.

16th February.—The 4th brigade of infantry, and Captain Grant's troop of horse artillery, passed over. The Commander-in-Chief, Sir Henry Fane, visited the bridge, and rode over to examine it.

17th February.—The cavalry brigade, consisting of Her Majesty's 16th Lancers, and the 2nd and 3rd regiments of light cavalry, crossed this morning. Two thousand horses, and five thousand five hundred camels, passed over without accident.[2]

18th February.—The bridge and stores were made over to the charge of Lieutenant Wood, I. N.

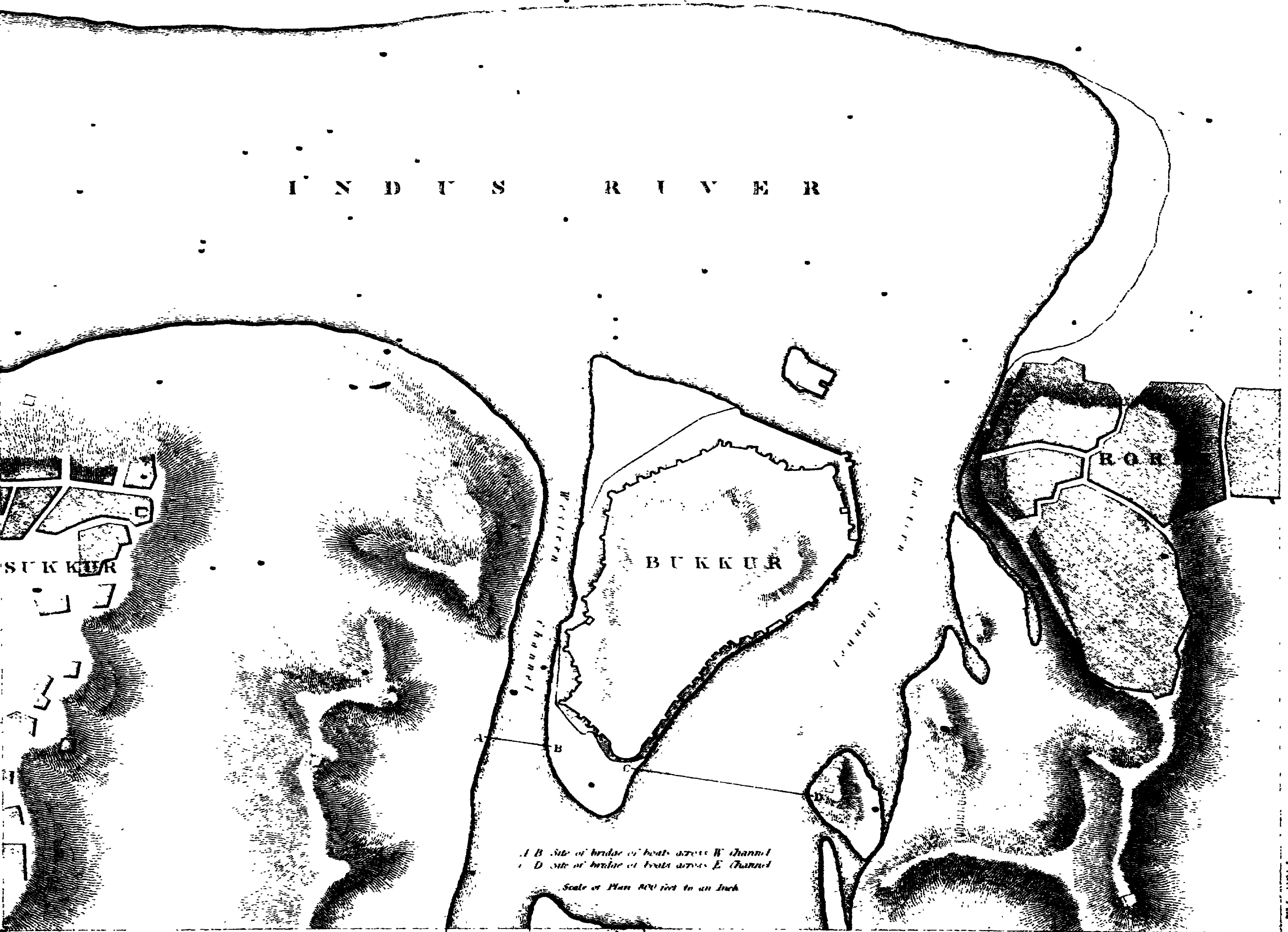
REMARKS.

The construction of a bridge of boats across the Indus at the season of the year in which it was undertaken, would not, had the necessary preparations been made, have offered difficulties of any very serious nature. The chief consideration was the great breadth of the river, and the quantity of material which such an extent of platform as was requisite would demand. The boats called sorak, which could have been easily procured in sufficient quantity, are admirably adapted to bridging purposes; but timbers for balks, and even planking, must necessarily be brought down from the Punjab, as there is nothing in Sinde which could have been made to answer for the platform of such a work. The date-trees, when cloven into thick rough kind of planks, answered indeed for the roadway; but from the weight of the tree, and its great pliability, unless very thick, it is ill suited for furnishing balks. The Talee or Sipoo tree is not abundant in the neighbourhood of Shikarpoor, and what there is of it is short, crooked, and heavy, but very strong, and was found useful in forming the anchors. Besides the difficulty respecting timbers, it was impossible to carry a sufficient supply

[2] The commissariat camels were, it is supposed, in number about 20,000.

of cordage from Hindostan; and, from the doubtful state of Sinde, it was almost as impracticable to have attempted obtaining this essential article from the Bombay dock-yards. The only recourse was, therefore, to have early commenced the manufacture of stout cables from the moorige grass which in parts abounds on the banks of the Indus. With these necessaries, timber, cordage, and boats prepared and collected in a sufficient quantity, and with the rough anchors used on this occasion, a broader part of the river, having a less violent current and a more favourable bottom, might have been selected, and many risks avoided to which the work was, under existing circumstances, necessarily exposed. The danger of failure would, however, have been materially diminished, had it not been for the unfortunate delay which occurred between the arrival of the boats of the sick on the 23rd, and those of the commissariat on the 30th January. During this time the flood which took place caught the bridge in a most unfavourable condition for resistance, and considerable apprehensions were entertained that if the river rose higher, so as to cover the low spit of sand between the western and eastern channels, the violence of the current, the isolation of the half-finished work, and its complete exposure to the full action of the remarkable oscillations of the flood from bank to bank, would cause the platform to break up, and the whole to be swept down the river. The cables were also under a heavy strain from the drift trees and brushwood which they caught; the anchors had not a good soil upon which to hold, and the continuance of the flood threatened to render both evils still more irremediable. Had the whole of the boats arrived so as to have enabled the completion of the connexion between bank and bank, the risk from the lateral fluctuations of the flood would have been altogether avoided, and the structure have had more strength, compactness, and stability. The work, when finished, was again subjected to a trial, which, considering the nature of the river, the approaching period of its annual rise, and the very temporary efficiency of the moorige cables, was one full of hazard. The interval between the 3rd and 14th February was, with the exception of the passage of the artillery park, occupied by nothing, except what it would have been an advantage to have avoided, namely, the crossing and re-crossing of unladen commissariat camels. By great good fortune only one serious accident occurred, which was quickly repaired; but as there was scarcely another spare boat at hand, the hazard incurred by the crossing and re-crossing of the commissariat cattle was great. In addition to which, every day's delay told seriously on the cables, which were rapidly wearing from the action of boughs of trees brought down by the flood; for these, fixing by their forks athwart the cables, were kept in incessant vibration by the action of the stream, and gradually cut the cables through: some of these thus destroyed had every appearance of having been cut with a knife; and had it not been for the depth at which the break took place, suspicions that such was the case might have been entertained.

Had the Indus not commenced rising when it did, two or three days after the



John Weale, Architectural Library, 59, High Holborn

passage of the troops, Lieutenant Wood would have been able to maintain the communication but a few days longer, so serious was the wear of the cables from the above cause.

The commencement of the periodical rise forced the above officer to dismantle the bridge shortly after the departure of the troops for Shikarpoor.

(Signed) H. M. DURAND,
Lieutenant Bengal Engineers.

Dehli, February 20, 1840.

VII.—*On Lodging Troops in Fortresses at their Alarm Posts. By Lieut.-Col.* Reid, *Royal Engineers.*

The object of this Paper is to invite inquiry, how far it has been necessary, in consequence of the invention of cannon, to give up defensible quarters for garrisons (such as the towers in ancient fortifications frequently afforded) upon the tops of the ramparts they have to guard and defend, and whether the re-introduction of such a practice would not add to the security of fortified posts.

The principle which I wish here to propose for consideration may be explained thus: When a decision has to be made upon a site for the lodgement of troops within a fortress, and intended for its defence, the first object for consideration should be the proper distribution which its commandant ought to make of his garrison on alarm; and then to conform to this distribution as nearly as possible in selecting the sites for building the soldiers' quarters.

If this distribution could be exactly conformed to, then each portion of the garrison would be quartered at its alarm posts. That portion allotted to repair on the first alarm to the ramparts would be already there; whilst the reserves, hospitals, and magazines, would be in the centre of the fortress.

Nor would such a disposition of soldiers' quarters in forts or fortresses be advantageous only as affording greater security against assault: military officers, who in war have to keep guard on ramparts, constructed like those after the school of Vauban, with no shelter upon them but traverses of earth to stop raking shot, well know the loss that accrues from sickness to soldiers, when kept as sentries, exposed to sun and rain. The consequence often is, that the number of efficient men in a garrison is much reduced by disease, at the moment when they are hard-pressed and most wanted.

The garrotte of Vauban, at the salient angle of bastions for a single sentry, fulfilled this object of protection from weather. Built of stone, and projected on corbels from the wall, it was musket proof; whilst it overlooked the ap-

proaches. The value of these garrottes has been often felt and acknowledged; but, instead of being confined to the salient angle of the bastion, they should be erected wherever sentries are required to watch the approaches.

Any arrangement which should lead to soldiers living on the spot which it was their allotted duty to defend, would tend to diminish the number of ordinary guards required for a place, as well as give greater security; and it would also contribute to preserve the garrison in an efficient state as to health. Nor are daily guards, sent from barracks in the interior of a town, perhaps to a different post each time they are put on duty, likely to be equally efficient for the security of their posts, with those who have distinct allotted posts to defend, and who may study the best means of maintaining them.

Military guards, placed at the gates of modern fortresses, are usually daily guards; and it has become a practice almost general to erect what is called a guard-house in the form of an ordinary civil building, without any regard whatever to its aiding in the defence of the gateway.

The principle I am desirous to advocate would make the lodgement for the guard, at the gateway of a fortress, the best position for the defence of that gateway; and when a guard in such a position is visited by the officer on duty, I would venture to propose, instead of the guard turning out of the building, (according to the present regulation,) that the command should be, for the men to stand to their posts. Long impressed with the reasonableness of this change, I introduced it into practice when in command of infantry in 1835-6. Those guards opposite the enemy, which by the regulations were required to turn out to officers of a certain rank, paid that compliment by standing to arms and repairing to their alarm posts. The effect of this system was, that the superior officer, receiving the compliment, had the advantage of seeing whether the guards knew how to take up their posts for actual defence; and the soldier acquired a habit of repairing to his alarm post with alacrity. Thus every individual is required to be seen actually placed at his position for defence: whereas, by the present system in British fortresses, soldiers are often relieved from their duty on guard without knowing any thing about the defence of their posts, although there can be no doubt but that military training, during peace, is intended to prepare them against actual warfare.

Engineers in modern fortifications appear to have too hastily given up the use of walls, except such as shall be capable of resisting heavy cannon. Experience has shown, that the quantity of shot expended to demolish any great

extent, of even thin wall, is worthy of calculation. There are many countries, in which war is carried on, which do not afford the means of transport for the conveyance of the shot needful to destroy an extensive wall of this latter nature. Defensible buildings, therefore, even if exposed to cannon shot, will seldom be capable of entire destruction, without a great expenditure of ammunition. In most situations, however, barracks on the ramparts could be placed under cover; and if this principle be right, many healthy and convenient sites for the construction of new quarters for troops would be found already in the possession of the Government; and bastions and ravelins, now vacant, would be occupied as soldiers' quarters.

Quartering troops in casemates under the ramparts, although it forms part of the same system, does not secure the ramparts themselves against an enemy once getting a footing upon them. It is understood that the Austrians, in their new constructions at Verona, are partially following this system; and that they are placing towers at the salient angles of the bastioned lines, which will serve the double purpose of lodging part of the garrison, and flanking the walls at short distances.

Enclosing walls for barracks might render the defences more difficult to be overcome; for when communications along ramparts are easy and uninterrupted, an enemy in numbers, once obtaining a footing upon them, can extend along, and generally succeed in capturing the fortress. Radiating walls, which would interrupt his progress, might therefore be advantageously introduced into fortifications.

If in practice the principles suggested were to be carried out, we might have long lines of defence, suited to cannon, combined with short lines of defence, suited to musketry; and an enemy attempting to establish himself upon the ramparts, after passing across long lines, flanked by cannon, would come under the fire of musketry from the defensible quarters of troops on the tops of the ramparts.

In this Paper it is not intended to do more than indicate the principle, without entering upon details.

VIII.—*Memoranda relating to the Well in Fort Regent, Jersey.* *By Major* HARRY D. JONES, *R. E.*

THE principal object which attracts a stranger's attention upon landing on the pier of St. Helier, in Jersey, is the work called Fort Regent, which crowns the hill above the town. It is not my intention, however, in this Paper, to say any thing of the work itself, my object being merely to afford some information as to the means by which an inexhaustible supply of water has been secured to the garrison.

Fort Regent was constructed during the late war between Great Britain and France; the works were commenced about the year 1805. The fort is erected upon the town hill, a bold promontory to the south of the town of St. Helier, which it commands most completely, the town being built at the foot of the rock. The summit of the hill was about 170 feet above the level of high water: in its character it very much resembled Gibraltar; a bold rocky feature rising abruptly from the sea, and having scarcely any perceptible connexion with the hills to the northward and eastward, which encircle the town in those directions. The south hill is formed of compact sienite, weighing 165 lbs. per cubic foot; the rock is stratiform with vertical joints, the general direction east and west. There were no springs upon the surface of the hill, nor any thing indicating on the faces of the scarped rock that it contained such an abundant supply of water: it must consequently have been upon the conviction that water would be found by sinking to the same level as the water stood in the pigeon-pump, in Hill Street, (240 yards distant from the point where the well in the fort has been sunk,) that Major Humphry, the Commanding Engineer, was induced to recommend the attempt being made. The operation, although it cost much time, labour, and expense, has been most completely successful. After sinking through 235 feet of compact rock, and

Plate IX. Fig. 1.

upon firing a blast, the spring was laid open, the water from which immediately rose in the shaft to a height of 70 feet, and has rarely since been lower.

During the progress of the work water had been found at different points, but not in any quantity sufficient to retard the workmen, until the lucky blast above mentioned, when it poured in like a torrent, to the great astonishment of the miners, who were suspended in the bucket, waiting the effects of the explosion.

Plate IX. Fig. 2. By the sketch it will be seen that the level of the water in the well in the fort, and others marked *a*, *b*, *c*, is generally nearly the same. When the water rushed into the shaft of the well in Fort Regent, it was observed that the water of the pigeon-well had fallen several feet, and it has never since risen to its former height: this would have led to the supposition that the sources from whence Fort Regent well (*a*) is supplied, as also the pigeon-well (*c*) and barrack-office well (*b*), were the same, had not the dry summer of 1835 proved to the contrary. During that summer the pigeon-well (*c*) was dry, and the inhabitants were supplied with water from the barrack-office well (*b*), which, in consequence, reduced the water standing in it from 48 feet to 15 feet; at that time Lieutenant-Colonel Lewis, Commanding Royal Engineers, directed Mr. Henry Roberts, the Clerk of Works in the engineer department, to ascertain the depth of water in Fort Regent well, which was as follows:

1835,	March 2	86 feet of water.
	July 29	66 ,,
	August 24	70 ,,

In 1839 I caused the same operation to be performed, and I personally ascertained the temperature; the result was as below:

1839,	June 25	70 feet of water.
,,	Sept. 25	79 ,,

The temperature:

			In open air.	In well-room.	Water in the well.
June 25.	Well in Fort Regent	(*a*)	66° . . .	62°	50° Fahrenheit.
	Barrack-office	(*b*)	61°	,, ...	50° ,,
July 6.		(*a*)	69°	65°	55° ,,
		(*b*)	63°	,, ...	54° ,,
Sept. 25.		(*a*)	63°	61°	55° ,,
		(*b*)	61°	,, ...	60° ,,

These thermometrical observations must be considered as approximations only to the true temperature of the water, and are inserted to show that it varies, but not in a corresponding or proportionate degree with the variations in the atmospheric temperature.

Dr. George Jones, who has the charge of the medical department of the Ordnance in the island, very kindly, at my request, analysed a small quantity of water from the fort well (*a*) and the barrack-office well (*b*). I was desirous to ascertain whether there was any difference in the quality of the water, as the soldiers quartered in the fort prefer the water from the well (*b*), being, Plate IX.
according to them, softer and better suited for washing than the water in the fort well (*a*). The analysis showed a trifling difference in the proportion of lime; Fort Regent well containing about 4 grs. of fixed salts in a pint of water, and the barrack-office well not quite so much. The analysis of the water in both the wells showed the presence of sulphuric acid, hydrochloric acid, lime, magnesia, and soda. The difference in the amount was due to the smaller quantity of lime in the barrack-office well.

Plate IX. fig. 2, is a section of the hill in the state it was before the erection of the fort, and is drawn to show the general level of the water in several wells in the vicinity of the well in the fort.

This section is not laid down to scale, but the distances between the wells with respect to each other are marked upon the drawing.

The following details, extracted from the office books, will afford some idea of the difficulty of the operation, and the time and labour consumed in sinking the well. The work was commenced in December, 1806, and continued, night and day, until November, 1808.

Commenced 1806.	Number of miners per month.	Feet sunk per month.	Price paid per foot.
			Livres.
December .	14	13	60
1807. January . .	12	8½	72
February .	12	3	96
March . . .	12	9	108
April . . .			
May	12	5	120
June	12	11	108
July	12	8½	108
August . .	12	10¼	111
September .	12	10	108
October . .	12	9¼	108
November .	12	9	108
December .	12	9	108
1808. January . .	12	9¼	108
February .	12	7½	108
March . . .	12	10¾	108
April . . .	12	9	108
May	12	12¼	108
June	12	13	108
July	12	10	108
August . .	12	11¾	108
September .	12	9¼	108
October . .	12	9	108

Average cost, 10*s*. per foot.
Total expense, £2599 8 7½.

There were expended, during the progress of the work, of the following articles the under-mentioned quantities, viz.:

Candles	976 lbs.
Coals	1659 bushels.
Gunpowder	2848 lbs.
Lamp oil	82 gallons.
Miners' tubes	9852.

There are two cisterns, capable of holding 8000 gallons each. The water is pumped into them by machinery, to be worked either by horses or men; the same machinery being applicable to the working of a bucket,[1] in case the pump should be out of order: the pump is 4 inches diameter, with brass bucket and valves, with 195 feet of wrought iron rod, jointed every 10 feet, and 18 ten-feet lengths of 5½-inch iron pipe. Cost, £495 15*s*.

[1] The bucket is shown in the drawing, although it is only affixed to the barrel when required.

The machinery for working a bucket from the horse-wheel, independent of the pump, consisting of a barrel on the horizontal shaft, with clutch-box, lever, and pulleys for leading the ropes, cost about £35.

In the casemate over the well-room are two hand-pumps for raising water from the cisterns, to prevent waste, and for the convenience of the troops: these cost about £24.

The total expense, including the labour in fixing machinery or incidental expenses, amounted to £667 15*s.*[2] Thus, for a sum little exceeding £3000, there is obtained for the garrison an inexhaustible supply of excellent water. Twenty-four men working for two hours, without fatiguing themselves, can with ease pump into the cisterns 800 gallons of water.

The island of Jersey, for its size, is probably more abundantly supplied with water than any other space of equal area. At Plemont, near Point Gros Nez, almost the highest feature in the island, nearly 300 feet above the sea, there is a spring of fine water which has never been known to fail even in the driest seasons: the same again may be observed on the hill by the side of the road descending to Bouley Bay; the water is constantly running, and issues from the rock, which in this district is *kaolin.* A few years since, Lieutenant-Colonel Oldfield sunk a well in the yard of Rozel barracks, only 40 feet within the line of high water, 30 feet deep, through rich loam; there are 15 feet of excellent water standing in it, the surface of which is 6 feet lower than the level of high water. Had the island of Jersey been composed of different stratified rocks, springs appearing in such different situations might have been accounted for by its geological formation; but the island is a mass of sienite in the north, hard and compact, varying in quality to the south and east, where it is found completely disintegrated. Whether water is to be found generally in sienitic rocks, or whether the subject of the numerous springs in Jersey has been noticed by geologists, who have examined the formation of the island, I am ignorant: if not, it may be found worthy of attention, and afford an interesting study to some of the numerous strangers who visit the island.

I cannot close this Paper without relating what took place in my presence last September, and which enables me to add my personal testimony to that of

[2] The machinery was supplied by Henry Maudslay and Co., London.

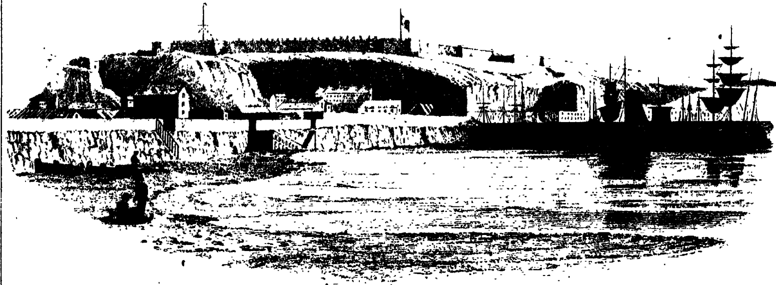
many others who have testified to the fact of the use of the divining rod in discovering water.

His Excellency Major-General Sir Edward Gibbs, K.C.B., the Lieutenant-Governor, mentioned to me, that if I was desirous of seeing the experiment tried, he would send for one of the two or three persons in the island who only were gifted with the extraordinary power of pointing out, by the aid of a hazel-twig, where water could be found. Having expressed a particular wish to witness the operation, His Excellency procured the attendance of M. Ingouville, a respectable farmer, about seventy years of age, who came prepared with his *baguette divinatoire.* The baguette is a forked twig of hazel, about 18 inches long from the fork; it is held in the hand in the position as represented in the drawing, and as the person approaches the spot where the water is to be found, a tremulous motion is observed in the twig, which, as the holder of it advances, by degrees commences bowing its head, until it becomes completely reversed, and pointing to the ground.

Plate IX Fig 3

A fortunate circumstance occurred, doing away with every suspicion that the twig which M. Ingouville brought with him had undergone any previous preparation, by which he could effect the extraordinary motion in it which we had observed. One of the party, in trying the experiment, pulled the arms of the twig asunder; another twig was cut from a tree in the Governor's garden, and the operation repeated with equal success by M. Ingouville; but, strange to say, when in the hands of any other person, the twig remained immoveable · in one particular spot the motion of the twig was almost instantaneous. In order to ascertain whether there was any trick on the part of M. Ingouville, after he had grasped the twig, I took firm hold of one end of the rod, and one of His Excellency's servants the other; but notwithstanding our endeavours to prevent the twig from bowing its head, our efforts were vain; and when M Ingouville opened his hands, the fibres of the rod were found to be completely twisted. Major Poingdestre, His Excellency's aid-de-camp, Mrs. Jones, as also one of the servants, were present, and all made a trial, but without success. M. Ingouville stated that a French emigrant priest mentioned to him how it was to be done; but he cannot account for the twig bending in his hand, and not in the hands of other persons. M. Ingouville states that the motion of the rod depends upon the abundance and depth of the spring below the surface. The nearer the water, the more violent is the tremulous

Fig 1



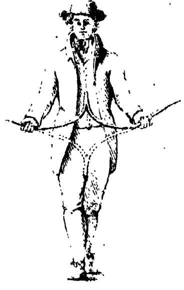
VIEW OF THE HARBOUR & FORT REGENT

(Copied from F. Le Gros's Map.)

SECTION
of the
TOWN HILL, JERSEY,

on which Fort Regent has been erected,
shewing the level of the Water in the Well of the
FORT,
and others in its immediate neighbourhood.





Baguette Divinatoire *Fig 3*

Fig. 2

Surface of Town Hill before Fort was constructed

Level of the Parade

Barrack Office Well

Harbour Well

Pigeon Well

Low Water Line

Water 25th June 1839

Low Water Line Spring Tides

Scale of Heights

50 100 feet

600 Yards

250 Yards

b a c

Note *On the 25th June 1839, the height of Water in Well marked* a *was 72 feet being 1 foot 6 in.s above High Water Line*
b *was 17 feet 6 ins being 4 feet 6 in.s below d.o*
c *was 20 feet being 9 feet below d.o*
Harbour Town Well was 42 feet being level with High Water Line ...

motion: from practice he is able to state with tolerable accuracy the depth to which it will be necessary to sink a well before water will be found. Several wells have been sunk with perfect success on spots pointed out by him, and water was found nearly at the depth he had mentioned.

HARRY D. JONES,
Major Royal Engineers.

Shannon Commission Office,
Dublin, March 20, 1840.

IX.—*Notes on the Island of Ascension.* *By Captain* H. R. Brandreth, *R.E.*

In the year 1829 I received instructions from the Admiralty to proceed to the Island of Ascension, to make a report and survey of the island previous to the adoption of certain measures recommended by the Commandant, Captain Bate, of the Royal Marines, which would have the effect (if sanctioned) of confirming the final establishment of the island as a permanent station; and my attention was principally directed to three points: 1st. The defence of the island, and the necessary means of accommodation for the troops. 2nd. The means of procuring water, and of conducting the supplies from the mountain district to the town. 3rd. The state of cultivation, and the encouragement necessary to raise stock and vegetables for His Majesty's ships of war, and merchant ships of any nation, touching at the island.

I was also directed to report generally on the condition of the island in reference to its existing and probable future means as a colony.

General description.

Ascension is situated in 7° 55′ 56″ south latitude, and 14° 23′ 50″ west longitude. It is about eight miles in length, and six in breadth, and lies within the immediate influence of the south-east trade wind.

The whole character of the island is volcanic, and its surface is broken into mountains, hills, and ravines. The mountain district extends principally over the south-east portion of the island; and the "Peak," or greatest elevation, is 2870 feet above the level of the sea. The plains or table-land surrounding the "Peak" vary in height from 1200 to 2000 feet. On the north side they sweep gradually down towards the shore, but on the south they terminate in high and bold precipices. Steep and rugged ravines intersect these plains, which, commencing from the highest lands, open into small bays and coves on the shore, fenced on each side with masses of compact and cellular lava. The sides of these ravines disclose extensive beds of cinders and ashes. Volcanic tufa occurs in the form of rocks, but is in general distinctly stratified. Red

iron clay, tufa, blue clay (resembling marl), and decomposed trachyte, alternate with the strata of cinders and ashes, and, wherever recent sections occur, present the most distinct arrangement. Pumice is found on the plains and corresponding parts of the mountain district, and occasionally on the shore. It is found in detached pieces, or mixed up with cinders and clay, and occasionally with a conglomerate of red iron clay, cinders, ashes, scoriæ, and nodules of lava. Trachyte rock appears to extend all round and throughout the mountain district; in several parts resembling the arrangement of basaltic columns, and in others chalk cliffs. Masses of this rock disclose themselves near the mountain ridge, and it passes from the compactness and hardness of sandstone to entire decomposition.

The hills dispersed over the island vary in height from 1000 to 1500 feet above the sea, and offer, with few exceptions, no evidence whatever of having undergone any change since their volcanic origin. They abound with cinders, scoriæ, and ashes, and are surrounded at their bases with compact and cellular lava, and occasionally with obsidian. They in general possess vestiges of an original conical form, having the surface smooth and regular towards the north; but on the south they are broken, hollow, and precipitous, with here and there the appearance of a lateral discharge of lava, which may be traced in its course towards the shore.

Plains of cinders, ashes, and scoriæ, and finely pulverized earth, spread over that portion of the island which lies to the north-west of the mountain district, intersected with water-courses of fine gravel, and pebbles of lava and silex. Masses of lava and scoriæ also occur on these plains, 20 or 30 feet high, heaped together as if by art, and for the purpose of clearing the land.

Extensive beds of lava and scoriæ surround the island, indenting the line of coast with small bays, coves, and inlets.

From north-east bay, south, to south-west bay, the coast is singularly bold and precipitous. On the opposite coast the beds of lava spread out into the sea, and assume a variety of forms, columnar, arched, or cavernous; and their surfaces are remarkably rugged, splintery, and difficult, and even dangerous for the stranger to traverse. These formations are locally termed "climpers." Stalactites of sulphate of lime are found in the coves on the shore.

Limestone occurs in great abundance in some of the bays and coves. It is a beautiful specimen of calcareous tufa, consisting of small particles of shell, rounded by attrition, and united by heat and pressure. Excellent lime is

obtained from it, which, when mixed with three, and even four, parts of the volcanic earth, forms good mortar.

The dark and rugged beds of lava, the deep red colour of the hills, the wild and capricious forms of the mountains and precipices, and the prevailing *apparent* recent indications of volcanic action, impart to the aspect of the island a character of total sterility and desolation that does not really belong to it. It is important to notice this, as the impression made on the transient visitor is perhaps to the last degree unfavourable; while a detailed examination of the features of the island is calculated in some degree to remove this impression.

Population. The population, at the period of my arrival, consisted of about 140 Europeans, principally of the Royal Marine corps, and 76 Africans; making a total of about 220 persons, including military and civil officers, and a few white women, (the wives of the non-commissioned officers and privates of the Royal Marines), and black women and children.

Establishments. Town, &c. Ascension was first occupied as a post by Admiral Sir George Cockburn on the arrival of Napoleon Buonaparte at St. Helena, to aid in the surveillance of that island; and was placed on the establishment of a sloop of war. A small town, or rather village, thus grew up near the roadstead; which on my arrival consisted of a collection of miserable tenements, with walls put together without lime, and harbouring vermin; roofs of canvass or shingles, and floors of sandstone or tarras. The hospital, which occasionally received the sick of the African squadron, was placed in a hollow, and consisted of four rooms, each about 16 feet by 11; and the Africans occupied wretched hovels, dark and filthy. A victualling store, a tank, and a small stone tenement for the officers, were the only buildings that redeemed the establishment from the appearance of an African village. In the country, a mountain district, the accommodations were somewhat better for the officers; but the establishment generally was similar to that of the town.

Anchorage. The principal position, called George Town, already alluded to, lies on the north-west coast. It has an open roadstead, with good anchorage, about three quarters of a mile from the shore, in twenty fathoms water. The anchorage was defended by a few guns, on a projecting slip of land, about 70 feet above the sea, but without any breast-work or other cover; and in the rear, on a higher elevation, a building with a canvass roof was occupied as a powder magazine. Nearly parallel to this position was a second slip of land, of lower

elevation, which had been formed into a pier or landing place, protected at the head with masonry, and with a flight of steps to the water. Landing place.

The main road of the island communicated between George Town and the mountain establishment near the "Peak." The road was traced over the cinder plains, and round the base of the hills, and ascended over a steep spur of the mountain by several zigzags. The road was well traced, and extremely creditable to so young an establishment. It was probably easily worked out of the cinders and ashes, but from the same cause easily liable to decay. Roads.

Other roads, or rather tracks, had been worked in the lava district, and around the mountain lands; but the greater number were imperfectly executed, were traversed with difficulty, and scarcely one of them admitted the passage of a carriage of any description.

The supply of water at this time was scanty and precarious. It depended on springs, or rather drips in the precipitous banks, and the rains that could be collected in casks and a few old iron tanks. A stone tank at George Town, calculated to hold about eighty tons, was supplied with water from the mountains, a distance of six miles. Three carts, six oxen, and three drivers, were employed daily in the transport of about three hundred and sixty gallons of this water. The supply from the whole of the drips was estimated at about four hundred and eighty gallons per day; but even this quantity was liable to considerable diminution after long droughts. It does not appear that there had been at any one time one hundred tons of fresh water in store on the island. Water.

Several attempts had been made to procure a further supply of water by boring. The auger had been introduced nearly *horizontally*, or in the direction of the substratum; along which it was supposed the water passed, and formed a drip on the face of the precipice. The object, I presume, was to cause the stream to flow more freely; certainly not to arrive at the source of the spring. But besides this, the Commandant, acting on the advice of an eminent naturalist who had visited the island, sought for water by the usual process of boring. The spot selected was near high-water mark, on account of the neighbourhood of calcareous tufa, in the formation of which fresh water was considered an indispensable agent. The experiments were attended with great labour, and were unsuccessful. Those concerned in them were probably not aware that, according to experiments, the vapour from salt water, intensely heated under pressure, will, by passing through loose sand, agglutinate the particles and form the solid sandstone of Ascension without the agency of fresh water:

consequently, that this would not necessarily be found in its neighbourhood. A second trial for water in the low lands was decided on by the Commandant and myself; and in the event of failure, I recommended other trials to be made in the mountain district.

Productions. In reference to agricultural productions, the island might at this time have been divided into four parts.

The first part consisted of about two hundred acres, situated in and about the highest land. In most mountainous countries cultivation commences from the shore and ascends to a certain height, beyond which it is unprofitable; and nature is usually left unmolested and untamed. In Ascension precisely the reverse occurs: decomposition commences from the apex of the mountain, spreads down its sides, and is limited at certain stages, where the state of the atmosphere ceases to aid in altering the original volcanic condition of the soil. The first or highest portion of the land therefore is the richest, the vegetable soil being here occasionally from 2 to 3 feet deep; and in the ravines and hollows an alluvial deposit of greater depth is found, the substrata being cinders, ashes, and clay.

About forty-five acres of this, then, were in cultivation at the time alluded to, producing the sweet and English potato, peppers, tomatas, cassava, calaloo (or West Indian spinach), carrots, turnips, cabbages, pompions, French beans, and a few pines, bananas, and water melons. The Cape gooseberry (physalis edulis), a very grateful fruit for a tropical climate, was also found wild over this district. The sweet potatoes were as good in quality as any I had seen in the West Indies. The English potato did not thrive equally well, as is usually the case within the tropics.

Of the several wild plants that I found, scarcely any were useful; they were for the most part tropical, and of the worst kind, being important only as forming a basis by their decay for the improvement of the soil.

On my return I submitted these plants, and portions of the soil in which they grew, together with sections of the ground, and the meteorological observations I had made with Daniel's hygrometer, to the Secretary of the Horticultural Society, who expressed an opinion that the soil and climate of the mountain district were favourable to cultivation.

The second division of the island consisted of about seven or eight hundred acres, lying around the "High Peak," from about 1400 to 2000 feet above the sea. The soil here varied in depth from 6 to 18 inches, lying on beds of

cinders, ashes, scoriæ, and trachyte. The cattle and other stock grazed over this portion, and part had been planted in turnips. The temperature was steadier than that of the higher land, but less moist.

The third part or division of the island included those tracts of cinders and ashes that lie about all the lower lands. The only change that takes place in these hot and arid regions is after heavy rains: the thirsty soil rapidly absorbs the moisture; and the purslain springs up, and singularly contrasts its bright green and succulent leaf with the parched and waste surface. The only other evidences of vegetation are patches of hard wiry grasses. If, however, this district were visited with a degree of moisture like that in the mountain-lands, the soil would decompose, and be rendered capable of cultivation.

The fourth and last division of the island consists of extensive beds of lava, that will not undergo any change for an indefinitely long period.

From the examination of the records of the seasons, the concurring testimony of all residents, and my own observations, I consider the climate of Ascension to be decidedly, and in reference to its proximity to the equator, peculiarly healthy. Climate.

The difference between the heat and moisture of the mountain establishment and George Town is considerable.

In the former, the thermometer ranges, during the year, from 62° to 80°, and averages 70°; in the low lands the thermometer ranges from 70° to 88°, and averages 83°.

Daniel's hygrometer gave a difference of 10° in the mountain moisture over that of the coast, and the proportion of rainy days is as 3 to 1 nearly.

The temperature of the mountain district would appear better adapted to Europeans than that of the coast. But, from its elevation, it is very frequently enveloped in cloud and mist, and subject to greater changes than the coast. The latter is not only peculiarly healthy, but has the advantage of a drier and more equable temperature. It is perfectly free from marsh miasma, and from any of the usual sources of malaria in tropical climates.

According to the Medical Report, the complaints among the troops are: Remittent fevers—Dysentery—Hepatitis—Diarrhœa, and occasionally, Pneumonia—Rheumatism, and catarrhal affections. The former are peculiar to all tropical climates, but in this instance they occur under a mild type, and give way to the usual remedies.

The hot months of 1818 are recorded as having been sickly, owing, it is stated, to an unusually wet season.

In 1823, and at a much later period, some severe sickness prevailed in the island; the causes are not very distinctly proved, and I am greatly of opinion that they may be traced to imported disease from the African coast.

Convalescents from the African coast rapidly recover in the island.

The fact that the white men can work without injury seven or eight hours per diem throughout the year is important; and I observed that the general appearance of the troops was healthy, and little characterized by the usual effects of tropical climates.

The year is divided into two seasons: the hot months commence in December, and end in May; the cool season extends throughout the remaining months.

The rains prevail in the temperate season, but it does not appear that they are periodical in their recurrence.

The island is not known to have been visited by any severe tropical gales.

The "rollers," or heavy swells, are the most formidable obstacles to which the shipping is exposed. I am not aware of their having occasioned any damage to vessels, but all intercourse with the shore during their action is difficult, and even dangerous. At Tristan d'Acuña the same phenomenon occurs; and there, I believe, a vessel was on one occasion cast ashore by the violence of the rollers. I have never witnessed a similar action of the sea under precisely similar conditions elsewhere; but it is probably not very uncommon. The rollers set in from leeward, rising suddenly from a perfectly smooth surface, moving in long vast ridges towards the shore, breaking over it with considerable violence, and abrading the line of coast. The most remarkable circumstance attending the phenomenon is, that the waves rise without any apparent or hitherto detected warning, and subside as suddenly, and entirely. A space of ten minutes only has elapsed from the first moment of their appearing, to that of their final and complete cessation. Various conjectures have been hazarded as to the causes. The rollers differ essentially in their motion from the long swell that precedes or succeeds a storm; and from observations in the mountain, it would appear that they act only in the immediate neighbourhood of the island. It is possible that they may originate in volcanic action, occasioned by vapour generated below the bed of the water, and producing a sudden impulsive force upwards.

Having submitted to the Admiralty a Report on the island, with certain propositions for the future improvement and establishment of this little colony, and the Lords Commissioners having approved of the same, I was directed fully to explain my views to the Commandant, and to mark out the principal works.

The objects of importance were:

1st. The occupation of certain points with sea-batteries for the defence of the coast.

2nd. Accommodations for officers and privates,—a hospital, storehouse, workshops, &c.

3rd. A line of iron pipes for conducting the water from the mountain to the town, tanks, &c.

4th. Certain measures for the cultivation of the ground, rearing stock, &c.

I had previously consulted with the Commandant regarding these propositions, many of which, indeed, originated with him, and were merely referred to me as professional points, and to arrange the necessary details. In all essential matters our views were in accordance.

1st. Defences. Defen

I found, on my arrival, only one position occupied with guns; it was the slip of land before alluded to, about 70 feet above the sea, and called Fort Cockburn.

On this small plane were mounted on wooden carriages without any parapet, or cover, or even platforms,

Four 18-pounders	. . . . .	Guns.
Two 12 ,,	. . . . .	do.
One 32 ,,	. . . . .	Carronade.
One 12 ,,	. . . . .	do.

The magazine, of loose stones and canvass roofing, stood in rear of these guns, and on a higher elevation.

The object in occupying this position was to defend the landing on each side of it; and so far it was important: but in its then condition it was obvious the position was not tenable, and therefore the defences of the island might be considered wholly inefficient.

In proposing a plan of defence for the island, it was of primary importance to consider the probable personal means of the garrison.

To maintain a respectable position, and to defend the accessible parts of the coast, it would be necessary to have at least 400 men at command: 100

men would be dispersed among batteries between Pyramid Point and Nicholls' Bay (vide plan), for the defence of the coast, and the remaining 300 men would occupy an enclosed work near the sea, capable of communication with the shipping.

There were but two positions in the island that admitted of such a work being constructed; the one at Pyramid Point, the other on Cross Hill.

Pyramid Point is about 2000 yards from Fort Cockburn; the position is elevated from 60 to 80 feet above the level of the sea, and the approaches protected by extensive and rugged beds of lava. A small inlet, called Comfort Cove, affords facilities for landing, and might be defended by batteries on the two projecting points of the shore.

There would be ample space for an enclosed work about 300 yards from this Cove. The ground presents great difficulty to the approach of artillery, and there are no commanding elevations in the neighbourhood that would be occupied to advantage by an enemy.

The ground, however, consists of masses of splintery lava, scoriæ, and cinders, and could not be cleared without great labour. The principal objection, however, is its distance from the town or establishment.

Cross Hill is about 900 feet above the sea: the rise commences about 400 yards from Fort Cockburn, and its summit is about 1500 yards from it. The hill consists principally of cinders and light earth, so that a space on the top could be easily made for an enclosed work. The approach from the south is difficult, and ascent laborious on all sides.

The range from the summit of this position would be too great, and the fire too plunging, to afford an efficient defence for the proposed barrack establishment on the ground towards the interior. By throwing out batteries at lower elevations on the sides of the hill towards Fort Cockburn, a communication might be secured with the latter, and, consequently, with the shipping. There would, however, be a considerable difficulty in supplying it with a large store of water.

The line of coast from Pyramid Point to Nicholls' Point affords the principal facilities for landing. Both N. E. Bay and English Bay will also admit of landing; but the steep and broken features of the country surrounding these latter Bays render the advance of an enemy extremely difficult.

Every other part of the coast is remarkably bold, and difficult of approach, and defended by beds of lava, or "climpers," as they are locally termed.

The coast, therefore, from Pyramid Point to Nicholls' Point appeared to be the principal line to be defended; and I proposed to occupy it in the following manner:

FORT COCKBURN.

On this position I proposed the enclosed work described in the Plate, having five 24-pounders, and a defensible block-house for 35 men.

Battery No. 1.—I proposed a tower with two 24-pounders mounted on the top, at Pyramid Point, to maintain a cross fire with Fort Cockburn, and to see into Comfort Cove. It is to be supplied with a tank and a magazine, and capable of an independent defence, accommodating 12 men.

Battery No. 2.—A small half-moon battery on Goat Hill with two 24-pounders, having a cross fire with Fort Cockburn.

Battery No. 3.—A tower of the same construction with Battery No. 1.

Battery No. 4.—A small enclosed work similar to Fort Cockburn, mounting five 24-pounders, with a block-house.

Battery No. 5.—A tower of the same construction as Batteries 1 and 3.

Batteries No. 3 and 5 are too elevated, being from 90 to 100 feet above the level of the sea; but there is no other ground more favourable to admit of batteries forming a cross fire with Battery No. 4.

These works, with the exception of Battery No. 2, were proposed to be enclosed, and capable of an independent defence, should a landing be effected. Battery No. 2, from its neighbourhood to the establishment, did not require the same security.

The foregoing works would require the following personal means:

Fort Cockburn	35	men.
Battery No. 1	12	,
,, 2	12	
3	12	
4	25	,,
5	12	,,
	108	

The principal object of these batteries was to defend the coast against such irregular attempts at landing as might be expected from one or two ships of war; and through the signal-posts at Cross Hill and the mountain, the garrison would gain information of the probable point of landing.

I proposed a magazine for 500 barrels of gunpowder to be situated inland, and at a convenient distance, and where it would be secure from accident.

The principal portion of the materials for constructing these works are to be found in the island, and are easily procured and worked. They will be described hereafter.

I recommended that all the guns should be of one calibre, and mounted on traversing platforms.

In conducting these works I recommended that Fort Cockburn and Battery No. 4 should be first executed, as affording essential defence to the most important points of the coast.

In reference to what I considered might be the general strength of the garrison, not including provision for an enclosed work or citadel on Cross Hill, I proposed the following scale:

1 Captain Commandant,
1 Captain,
5 Subalterns,
130 Non-commissioned officers and privates;

of which numbers I recommended there should be 1 Subaltern and 25 Non-commissioned Officers and Gunners of the Royal Marine Artillery, to be in charge of the batteries and stores, and to instruct the garrison in the exercise of the guns.

The following memorandum on the guns and traversing platforms I had recommended, was furnished me by the late Colonel Sir Augustus Frazer, K.C.B., Royal Horse Artillery, to whom I was much indebted for his suggestions.

"For Iron 24-pounder guns.

		Iron.	Wood.
Gun Carriages	Weight	21 cwt. 1 qrs. 0 lbs.	13 cwt. 2 qrs. 23 lbs.
	Price	£13 9s. 5d.	£18 12s. 2d.
Traversing Platforms	Weight	45 cwt. 3 qrs. 0 lbs.	18 cwt. 3 qrs. 19 lbs.
	Price	£43 9s. 11d.	£31 18s. 2d.

"These were prices when both iron and wood were dearer than at present; so that 20 per cent. full may now be deducted from the price of iron carriages, and 12 per cent. from that of the wooden ones.

"The weight of the iron carriage and platform is obviously much greater

than that of the wooden ones; but the guns on the iron platforms are readily worked by the usual number of men, and no difficulty has been experienced on this account. The recoils of the gun had been moderate and easy, and no instance has occurred of the gun recoiling off the platform. On the supposition that this might be the case, the hind trucks were taken off the garrison-carriage, the gun recoiling on the hind axle-tree; that is a convenient mode enough in the event of any of the trucks being disabled.

"All wooden garrison-carriages, made for wooden traversing platforms, will answer for iron traversing platforms. The guns can readily be elevated to 15° on the iron carriages and platforms, and the ranges may be taken as follows for 24-pounders:

	Ranges in yards with charges of		
	8 lbs.	6 lbs.	4 lbs.
P. B.	297	248	265
1°	720	661	581
3°	1240	1213	925
5°	1807	1590	1371
10	2870	2673	2513
15°	3510	3350	

At high elevations, easily obtained by taking off the fore trucks of the garrison-carriage on which the gun is placed, and putting the first axle-tree on another garrison-carriage, 24-pounders will range as follows at 36°:

With charge of 3 lbs.	3900	yards
4	4150	,,
6	4200	,,
8	4400	,,

"These are all ranges without wads, which should never be used unless the guns are under depression, as they sensibly diminish the range.

"The small difference of range with high and low charges is, perhaps, worth attention at a station where the store of powder may be limited.

"There is no doubt that iron carriages and platforms will stand the shock of the firing of the guns placed upon them; but it has been fully ascertained that they will break to pieces on being struck by shot. Nevertheless, in climates where wood is perishable, as well as for coast batteries generally, they are very valuable, from their obvious durability and economy.

(Signed) AUGUSTUS FRAZER,
Colonel Royal Horse Artillery."

New Buildings. Ascension, like St. Helena, lying in the immediate track of ships on their passage home from the East, might, if occupied by an enemy, furnish the means of considerable annoyance to our commerce.

The peculiar qualities of the climate render it a desirable place of resort for the African squadron, and for the preservation of stores for that station.

It was also considered that measures might be adopted for supplying ships in general with water and fresh provisions.

For these purposes the garrison was composed of a detachment of the corps of Royal Marines and a few African labourers.

The duties of the garrison were far from being purely of a military nature. The officers and men were employed throughout the day in erecting buildings, forming roads, tanks, and aqueducts, in cultivating the mountain district, and attending the cattle and other stock. These were all considered as public duties; and, in addition, the ordinary duties of the garrison were discharged.

The small community was, in fact, like the nucleus of a colony, but with the advantage of fulfilling all their various avocations in strict conjunction with each other, and under military discipline; and therefore unity of purpose, a most important feature in a young colony, was thus secured.

Hence the buildings for an establishment of this description would in some respects differ from those that are ordinarily required for a garrison.

At the principal establishment, George Town, I proposed to erect a barrack for 100 men, on the principle adopted by Sir Charles Smith, R.E., for the West Indies, together with quarters for the officers, a hospital for 30 patients, and a storehouse.

Plates X. XI XII The annexed drawings represent the fort and hospital that have been erected, and which are modifications of my original proposition.

Buildings on a similar construction were proposed for the mountain district, which have been erected, or are now in course of erection.

Smaller buildings, adapted to particular localities, and appropriated as detached dwellings, sheds, and other tenements for cultivation and stock, were also projected for the mountain district.

The island abounds in materials for buildings of masonry.

Limestone is found in the bays and coves, from the landing place to South-west Bay, which is easily quarried, and supplies both the material for mortar and building.

The limestone is the calcareous tufa, before alluded to, formed by the finely

comminuted particles of shell on the shore, dipping into the sea at a very low angle, and lying apparently in regular strata: masses, of considerable superficial dimensions, are worked out, and applied for paving, coping, &c.

The particles of shells of which the stone is concreted, are used for sand with the lime made from the stone, and mixed with sea-water. After a narrow examination of several buildings constructed with this mortar, I was not able to detect any saline efflorescence or other indication of moisture. The circumstance is to be attributed to the extreme aridity and equable temperature of the low lands. As fresh water was scarce in the island during the progress of the buildings, I did not object to the continued use of salt water, with the following exceptions:

1st. In situations exposed to much moisture.

2nd. In tanks, or, at least, in that portion of the walls in immediate contact with the water.

3rd. In powder-magazines.

4th. In ovens and fire-places.

Besides the particles of shell used as sand for compounding with the lime, several other materials were found applicable to this purpose.

Volcanic ashes and tarras, or decomposed basalt, were much used; and by adopting these materials in place of the sea sand, it was found that a much smaller proportion of lime was required, and consequently the expense of coal for burning lime was much reduced.

In addition to the calcareous tufa, there are three other kinds of stone more generally used for building.

1st. Trachyte, which abounds over the mountain district, and is easily worked out into blocks of any required size.

2nd. Compact lava, found in the low lands, and among the steep banks of the water-courses at the foot of the hills. This is the hardest and most durable material on the island, but is worked with so much difficulty as to be rarely used. It is employed, however, with greater advantage where large shapeless masses can be applied.

The third, and most general description of stone, is the common cellular lava, found in every part of the island; it is easily worked, and appears durable. It is occasionally found to decompose, but the artificers select that which is best adapted to their purpose.

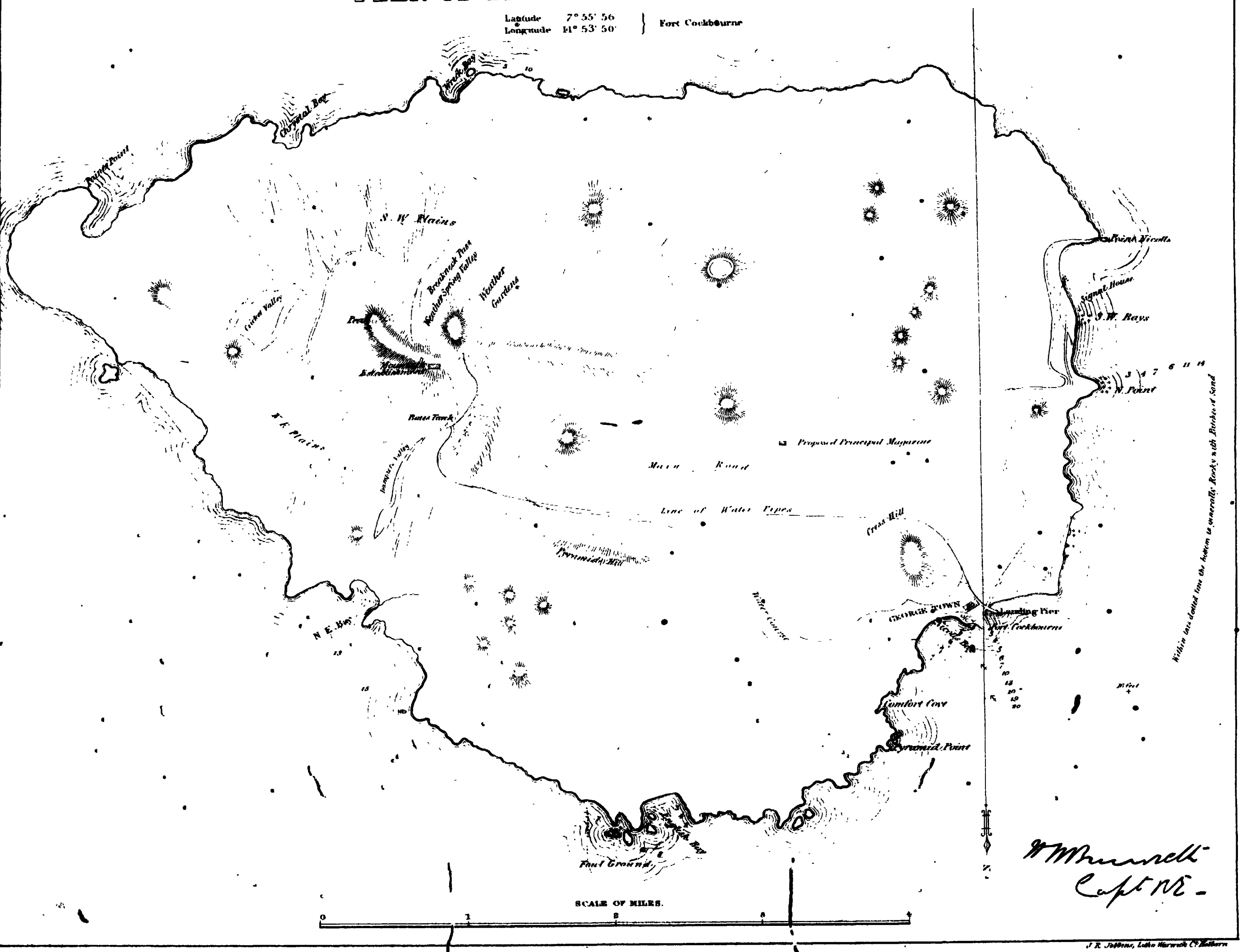
The water-courses supply sand for building near the mountain grounds: it is composed of fine gravel and minute pebbles of lava and silex, mixed with tarras.

The most important of the foregoing materials are procured with ease in the neighbourhood of any projected works.

H. R. Brandreth,
Captain Royal Engineers.

(TO BE CONTINUED.)

PLAN OF THE ISLAND OF ASCENSION.



PLANS AND SECTIONS OF FORT COCKBURN

D

A B

Magazine

Fig 1

F

Work House

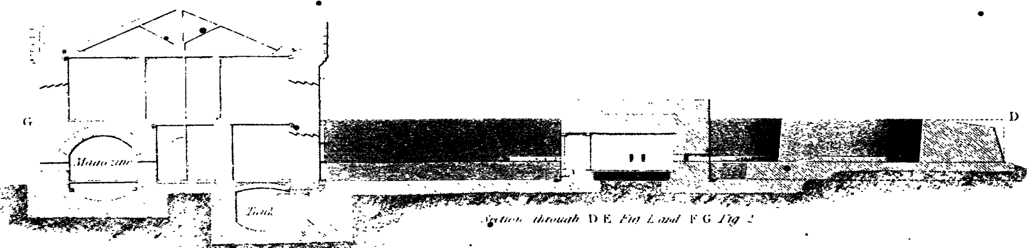
E

Fig 2

G

A B

Section through A B



Section through D E Fig 1 and F G Fig 2

Scale of Feet

G. Gladwin sc

John Weale Architectural Library, 59 High Holborn

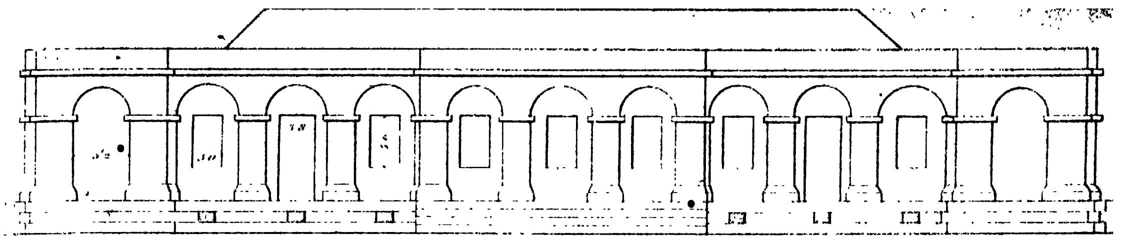
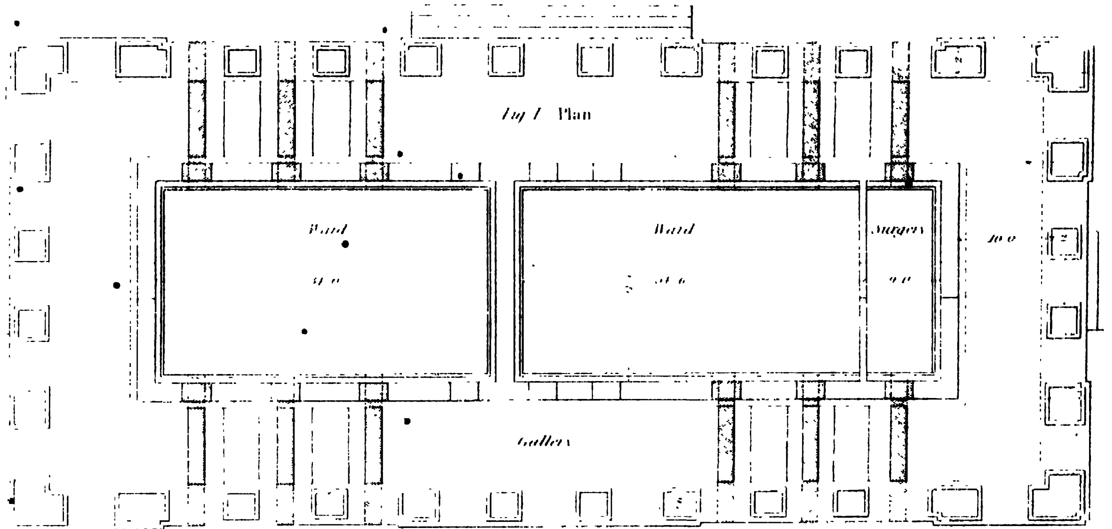


Fig 2 Elevation



Scale for Fig 1 & 2 16 feet to one Inch

Scale for Fig 3 8 feet to one Inch

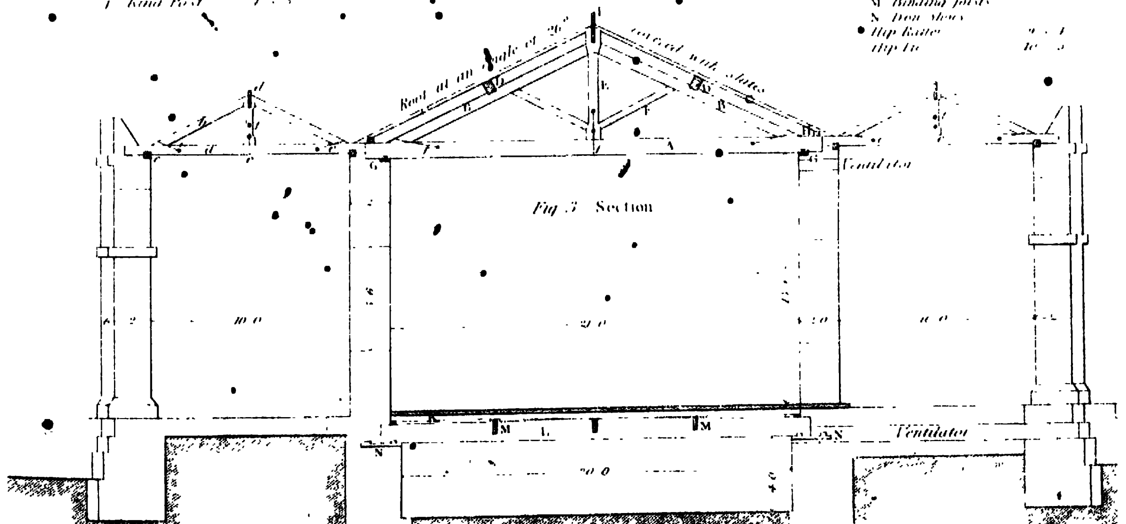


Fig 3 Section

X.—*Account of the Dam constructed across the Waste Channel at Long Island, on the Rideau Canal, in* 1836. *By Major* Bolton, *Royal Engineers.*

The following slight descriptive sketch of the dam constructed at Long Island, on the Rideau Canal, in 1836, was drawn up from notes taken during the progress of the work.

The waste weir situated on the left bank of the Rideau, a short distance above the stone dam at Long Island, was entirely destroyed by the spring floods on the 8th of June, 1836; and as the canal was thereby rendered useless for purposes of general trade, whatever steps might be contemplated to remedy the accident, the public interests required that that plan alone should be adopted which would ensure the re-opening of the navigation, not only during the then existing season, but also with the least possible delay.

In 1831, log crib-work filled with stone was placed across the waste channel Plate XIII Fig 3. leading into Mud Creek, with the intention of preventing a further erosion of its clay bottom, which was progressing with such rapidity as to cause serious alarm for the safety of the weir; but such precaution proved of no avail, and the floods of 1832 formed a deep excavation from the cribs to the apron of the weir. This excavation, after the waste weir was destroyed, was apparently, to a considerable extent, very compactly filled by the ashlar of the piers of the destroyed weir, and the large quantity of stone which for several years had annually been placed in front and rear of that work for its protection, affording, it was considered, a secure foundation; here, therefore, it was decided that a crib dam filled with stone, and planked with three-inch hemlock plank, should be constructed, to raise the water to the required height in the first place; keeping in view the possibility of its being made to answer also as a waste weir for the spring floods,—the second object to be attained.

The nature of the work, and the site it was to occupy, being determined, notices were issued calling for axe-men and labourers. Tents were erected for

their accommodation, measures adopted for provisioning the men at reasonable prices, (a matter of importance, as on it depended the rate of wages,) and for their being paid weekly; contracts for the supply of hemlock timber and plank entered into, temporary roads and bridges of communication formed, boulders were collected wherever they could be found, and parties were employed quarrying stone near Black Rapids, about four miles from Long Island; and these preparatory arrangements were so far matured as to allow of a commencement on the 23rd of June. The proposed plan of operations was, in the first instance, to form a flooring of timber squared on two sides across the channel; but, from the depth of water and strength of the current, this proved a much more serious and difficult undertaking than had been anticipated. Boats could not be used; the timbers had therefore to be floated down singly, by means of ropes; each log, on reaching the place it was to occupy, having one of its ends either resting upon the bank or against a timber already secured, the other end being forced at a slight angle against the stream, and retained in that position by planks, until an advance of fifteen or twenty feet into the channel had been made, when a second and third course of timbers were placed transversely and longitudinally upon them, and firmly secured to each other by oak pins 2 inches in diameter, and 3 feet 6 inches in length. When this had been done, a new advance in a similar manner was made, and thus, by working from each side of the channel towards the centre, leaving an opening to prevent the water rising too rapidly, was the object gradually accomplished.

Having succeeded in establishing a substantial flooring across the channel, profiles were set up, and the work was thenceforth carried on with regularity, and a due regard to form, allowing to the face of the dam a slope of 3 feet horizontal to 1 foot in perpendicular height: the open spaces of the cribs, averaging 2 feet 6 inches square, were filled with stone; but the difficulty of obtaining this material very much retarded our operations, as the steam-boat employed in towing could not bring up more than fourteen loaded scows a day.

Nevertheless, the work proceeded so rapidly, that on Saturday the 9th of July it was reported, "Very considerable progress has been made during the past week; the crib-work is up to the required height, the front part nearly filled with stone, and the wings planked: the closing of the opening is to be commenced on Monday, and will, I expect, be completed by Thursday evening, as well as the planking of the front of the dam."

The opening referred to was left wider in front than in the rear, designedly; for the first idea, on looking forward to closing the same, was to form a crib in the shape of a wedge, to be floated into the space, and thus to fill it up; but, on further reflection, such intention was abandoned, and the following plan adopted.

Oak posts were fixed, one on each side of the opening; against these, oak stop-logs were placed, and by sinking hemlock branches in their front, the carpenters, although the water rose rapidly, were enabled to proceed without interruption; and on Saturday the 16th of July the following report of progress was sent to the Commanding Royal Engineer:

"A party is employed to-day in filling in the centre crib-work with stone, and by to-morrow night I expect it will be planked and finished.

"The stop-logs in the accompanying explanatory sketch were got down on Thursday last, since which the water has risen five feet. Plate XIV. Fig. 1.

"I consider it necessary to extend the wings of the dam at *b b*, to secure the points *c c* from the action of the water when the floods are passing over the work. Fig. 2.

"The dam is much tighter (clay had not been placed in front of it at this period) than I could have anticipated, and by the next post I hope I shall be able to send a sketch of the mode to be adopted for providing a secure escape for the floods."

The bays of the front slopes of the crib-work were filled with stone packed as closely as possible, but the want of time did not admit of the same attention being given to the centre and rear bays, into which stone was merely rolled, the upper surface being levelled off; and, previous to planking, the spaces in the face of the dam were likewise filled in by additional timbers cut to the shape and size of the openings, by which means a compact and regular surface was obtained; but an equal bearing being a point of great importance, particular attention was given to it: wherever the least vacancy appeared, thin wedges were introduced, nor was a second plank placed until I was fully satisfied that the previous one had been properly laid down; carpenters were employed on this work, and the planks were fastened with 7-inch spike-nails.

Rafts and barges were passed through the locks without any interruption from the 1st to the 8th of August, at which period the depth of water on the upper sill was 4 feet 6 inches; so that within six weeks from the date of

commencing the dam, the canal was again navigable along its whole extent, and the first part of my instructions fully accomplished.

Having observed that the rush of water, when the old weir was destroyed, had not taken the least effect either on the crib-work placed across the channel in 1831, or upon the bed of the channel itself at its junction with Mud Creek, it occurred to me that the floods would pass off without causing injury, provided the force of the falling water could be broken by steps; I accordingly adopted this plan, and in my report on the subject, observed, "The rear crib-work for the water to fall over is commenced; the apron can be extended to any length that may be required, and it would certainly very much tend to the security of the work if it were carried down about 150 feet, and filled in with stone." This latter suggestion was not sanctioned; but experience has shown that it would have been the more economical plan, because the stone placed along the edge of the apron has to be renewed every second year, and this will, no doubt, have to be continued, until the excavation between the dam and Mud Creek shall have been thereby filled up nearly to the present water level.

Whilst finishing the apron, a considerable body of clay was placed along the front of the work, which, by rendering it water-tight, materially tended to ensure its durability, and removed every fear as to the possibility of its being undermined from the front, as had been the case with the old weir; and as 5 feet in depth of water is obtained by stop-logs fitted into standards fixed on the top of the dam, their removal affords an extensive space for the free escape of the floods, which for the last three seasons have passed off without doing any damage, and at the same time more quickly than formerly; and I can only add, that the work has hitherto fully answered the purposes for which it was intended. Plan and sections of the work in its finished state are shown in Plate XIV. Figs. 2 and 3.

Plate XIV. Fig. 5.

The average number of artificers, labourers, &c., employed daily, from the 23rd of June to the 23rd of July, was,—Carpenters, 6; Axe-men, 90; Labourers, 180; Double horse teams, 2; Single horse carts, 26; Yoke of oxen, 22. The sided hemlock timbers used in the flooring were 1 foot in depth, and 20 feet in length each: the under round logs 25 feet in length, and 1 foot in diameter at the small end; the upper logs 24 feet in length, and 10 inches at the least end. The quantity of sided hemlock timber used was 10,000 running

PLANS & SECTIONS OF THE WASTE WEIR AT LONG ISLAND ON THE RIDEAU CANAL.

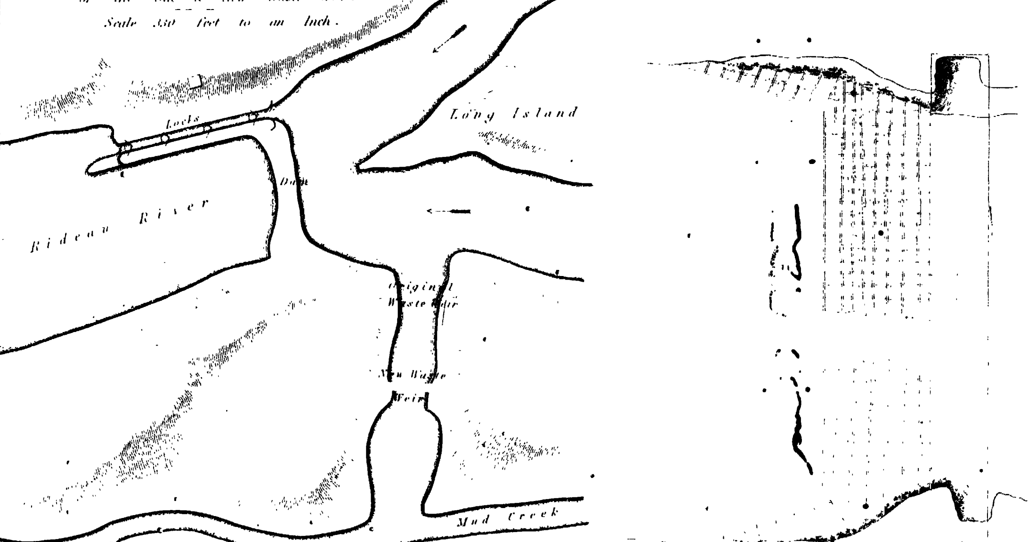


Fig. 1. Plan of the Works at Long Island shewing the position of the Old & New Waste Weir.
Scale 330 feet to an Inch.

Fig. 5. Plan of Flooring on 30th June.
Scale 10 feet to an Inch.

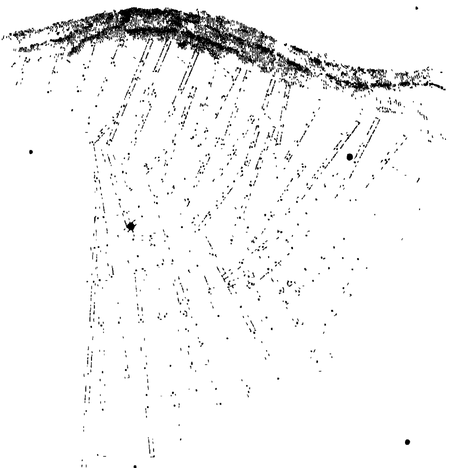


Fig. 4. Plan of Commencement of Work.

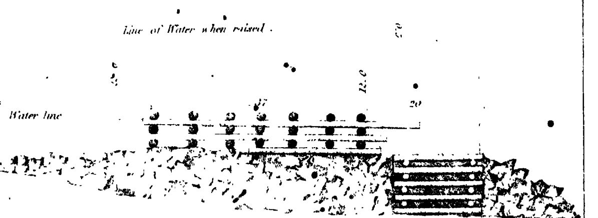


Fig. 6. Section across Flooring
Scale 20 feet to an Inch.

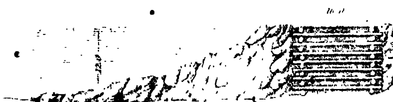


Fig. 3. Crib Work placed across the Waste channel in 1831.
Scale 24 feet to an Inch.

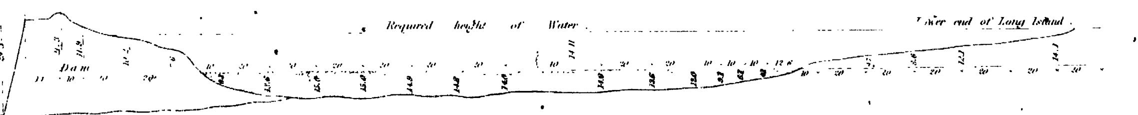


Fig. 2. Section of the Dam & the bed of the River above it.
Scale 45 feet to an Inch.

R.R. Davies sculp.
John Weale Architectural Library, 59 High Holborn

PLANS & SECTIONS OF THE WASTE WEIR AT LONG ISLAND ON THE RIDEAU CANAL.

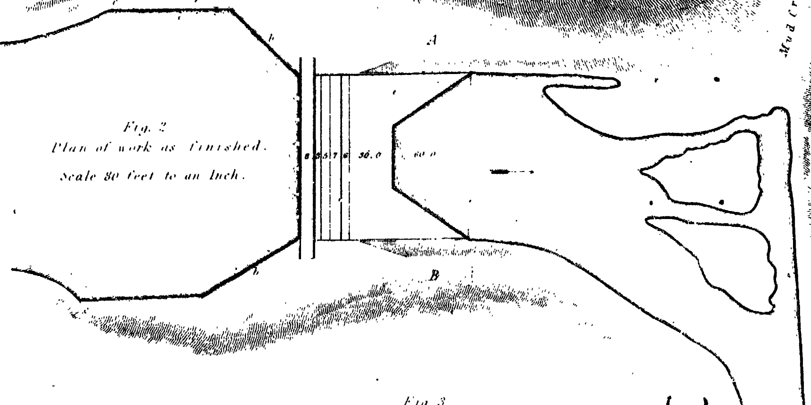


Fig. 2
Plan of work as finished.
Scale 80 feet to an Inch.

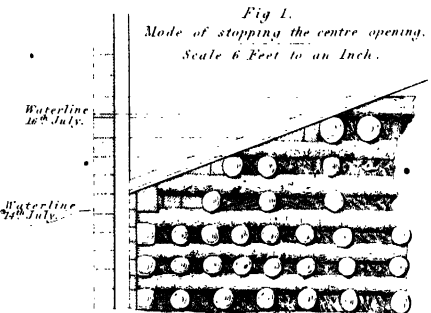


Fig 1.
Mode of stopping the centre opening.
Scale 6 Feet to an Inch.

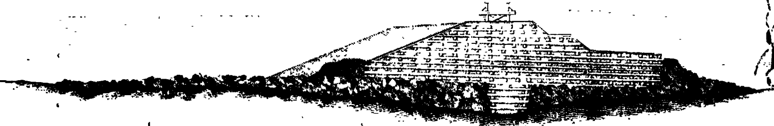


Fig 3
Section of work as finished
Scale 40 feet to an Inch

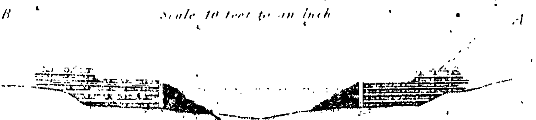


Fig 4
Section on Line A B Fig 2.
Scale 40 feet to an Inch

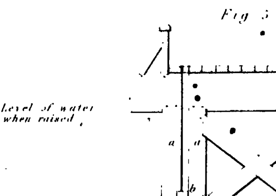
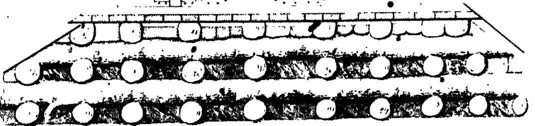


Fig 5



Section of Bridge over Dam showing the mode in which the water is raised 5 feet by Logs (b) slipped down grooves in the standards (a a).

John Weale, Architectural Library, 59 High Holborn

R.R. Davis, Esq.

feet; the number of round logs 2000; of oak pins 84,000. Quantity of 7-inch spike-nails 7900 lbs.; of 3-inch hemlock plank 35,000 feet: and the total expense of construction £3670 17*s.* sterling.

To build a dam exceeding 170 feet in length, which would support the weight of a column of water 22 feet in height, even under the most favourable circumstances, with the choice of materials, and with unlimited time at command, experience has proved to be no light undertaking; but without men, without material, not even stone to be obtained nearer than four miles, and then only by means of scows to be propelled against a strong current;—to construct in a deep and powerful rapid, discharging for the first fortnight after commencing operations at the rate of 190,000 cubic feet per minute,—a work of such magnitude, which would not only render the canal navigable within two months from its commencement, but likewise be of such strength and durability as to resist the force of spring floods passing over it,—such design (with the results of the failures at the Hog's Back and other stations clear in remembrance, and particularly under the difficulties to be surmounted), seemed quite impracticable; in fact, it was so deemed by more than one practical man: nevertheless, it was attempted, and most successfully carried into effect,—a result, I believe, without precedent in the annals of canals.

D. Bolton,
Major Royal Engineers.

XI.—Engineer Details. By Lieutenant NELSON, Royal Engineers. For the most part collected at Bermuda between April, 1829, and May, 1833.

PART I.—LABOUR, CHIEFLY CONVICT.

SECTION I.—*Data.*
SECTION II.—*Computations and Tables founded thereon.*

(Principally to show the Relative Values of Convict and other Labour.)

ALTHOUGH the circulation of this work of ours is not confined to the Corps of Engineers, it must be borne in mind nevertheless,

1st. That our professed object is the communication of practical information to each other.

2ndly. That our ulterior, though still distant, object, is to collect such experiences from all our stations as shall afford materials for a work like the *Aide Mémoire.*

Losing sight of the above, it would indeed have been bold to have published such mere apprentices' details as I have now offered; but there must be a beginning in this matter, and it seems to have fallen to my lot to bear the brunt of all comments in so doing. Be it so. It is, nevertheless, with any thing but the feeling of leading a forlorn hope, that I trust our brother officers will unhesitatingly bring forward useful details of every kind, for the information of their juniors; who, on joining the corps, cannot be too well apprised of their liability in the course of service to be called upon *to do any thing, at all times, and under any circumstances;* or be too well warned of the variety of fields for exertion ever before them, whether in peace or war, at home or abroad, so as to become INDEFATIGABLE and SYSTEMATIC observers.[1]

[1] One of the earliest occupations of an officer on joining a new station should be, the inquiry as to what may be learned there on professional subjects; and if he returns to an old one, the chances are that something else has arisen, in the mean time, worthy of observation.

Most especially has this view been followed out in exhibiting the construction of prices: these have been presented not only to elucidate much in the resulting Tables, but for study, as an example of the need of foresight and experience on one subject only,—estimating; and respecting the many circumstances that will arise in the formation of these, to defeat a very wide and, at the same time, very close circumspection, I give half a dozen of these prices as quite enough to show that much pains have been taken to form the Tables of Comparative Values of Labour.

In the following pages nothing concerning the purposes or position of the works will be mentioned, beyond stating that they related chiefly to the protection of the entrances to Bermuda at St. George's, and of its dock-yard at Ireland Island.

It is particularly requested that the two following remarks be remembered throughout:—

1st. That although it has been endeavoured to give what actually fell under my own observation a sufficient arrangement, yet a complete treatise is in nowise attempted; my only purpose, in this respect, having been to accumulate occasional notices where of possible utility.

2nd. That neither the possession of these notices, nor of any information whatever, can at all dispense with the necessity for acquaintance with those further and varying localities which have so decisive an influence in all estimates. Every station, every mile of ground in that station, has its peculiarities, many of which are liable to fluctuation: hence any application of the following remarks and calculations with a view of criticising the estimates of our brother officers, will be an unwarrantable perversion from their avowed intention; to say nothing of the *certainty* of error attending such procedure.

The contents of the following Paper are now submitted to the Corps, very nearly according to the analytical skeleton on which they were gradually collected, and which will serve as an Index.

PART I.—LABOUR, CHIEFLY CONVICT.

SECTION I.—*Remarks on the Convict System and Labour generally.*

(Data, principally for computing Tables of Prices and Daily Work.)

Task and Piece-work regulations at Ireland Island, } Convict.
Ditto at St. George's, } Convict.
Data for Excavation.
,, Ashlar, of sorts.
,, Burning Lime.
,, Mortar.
,, Masonry.
,, Brick-work.
,, Roofing with Bermuda Slate.
,, Ditto with Shingles.
,, Cementing.
,, Tar-work, Washes, Cements, Painting, Plastering, &c.
,, Sawyers' work.
,, Carpenters' work.
,, Smiths' work.
,, Diving-bell, Excavation, and Building.
,, Tanks.

SECTION II.—*Remarks on the Computations, and Explanation of the Tables.*

(Calculations founded on Section I. for Tables of Daily Work and Prices.)

Prices of Excavation.
,, Ashlar, of sorts.
,, Burning Lime.
,, Building, in Masonry
Table of Day-work, } giving Daily Work and Prices.
,, Task-work, } giving Daily Work and Prices.
,, Piece-work, } giving Daily Work and Prices.
Painting at Algoa Bay, as a specimen of War Prices in a colony.

GENERAL DESCRIPTION OF THE ROCK.

The Bermuda Rock is a stratified and calcareous sandstone; of all degrees of hardness and density, ranging from a loose sand to a compact limestone; the

sorts used in building varying between the softest Bath stone, and a second-rate Portland. The distribution of these varieties is most irregular: at St. George's, and generally throughout the islands, the former abound; but at Ireland Island, the eastern half is one quarry of the latter and harder description. Unfortunately for the Royal Engineer Department, though quite accidentally, the Ordnance works were situated on the worst portions, as the stone in general rose in blocks, not only irregular in shape, but texture, being full of sand-flaws, so that much labour and material were thereby wasted. Inside the dock-yard, on the contrary, their quarries gave them fine slabs of any dimensions, and of a sounder material; their wharf-walls required much larger and finer pieces than our rubble-headed rock could have afforded. The consequence of the sand-flaws above mentioned is, that in high and massive masonry the stone is apt to crack down the face; and thus, though seldom productive of serious consequences, gives an undeserved character of bad workmanship to one's performances.

Nor were these sand-flaws by any means always on a small scale: *throughout the islands,* large sand-pits abound in the heart of the soundest portions; and when the sea gains access to any of these soft masses that are on a level with it, they are thereby withdrawn; and thus, I presume, are most, if not all, those caverns formed, which occur so frequently, and so much to the destruction of all certainty in estimating time and expense. In consequence of such a cavern, one curtain was retired twice.

Caverns are rarely found in any but calcareous rocks; though the almost certainty of their occurrence in these may be relied on with so perplexing a confidence, that no ordinary estimate for works in a limestone district can ever be depended on. The grotto of Antiparos; the caves of Plymouth and Kirkby, as famous for their accumulations of organic remains as those of Gaylenreuth and others in Germany; the various Derbyshire caverns; Peter Frazer's bear-den in Nova Scotia; the different subterranean courses of certain rivers in England and elsewhere, are all to be found in the limestones of different formations.

Such caverns may at any time occur in the field allotted to the exertions of the Engineer, without the slightest indication above, of their existence beneath; and consequently, without the slightest blame being imputable for the necessary alterations in, not faults of, his original estimate.

Part I.—Labour, chiefly Convict.

Section I.—*Data, principally for computing Tables of Daily Work and Prices.*

(Remarks on the Convict System and Labour generally.)

Little is needed to exhibit the expediency of employing convict labour on works executed by the Admiralty or Ordnance. After a long acquaintance with its results, I am convinced of its efficiency where circumstances permit its adoption: in support of such conviction, I exhibit the results of from four to six years' close observation, in the three Tables given hereafter, on which this opinion is founded. For explanations of these Tables see Section II.

The workmen employed in the Royal Engineer Department at Ireland Island, and subsequently at St. George's, were principally convicts at 3*d*. per day, under the superintendence of sappers, and the control of the foreman of works, who thus carried into effect such directions as he received from the Engineer officers.

The systems of labour, generally followed, were those of task-work and piece-work; long experience having shown that, with very few exceptions, the day-work plan amounted to no more than an experiment of *how little* could be done for any assigned amount; and it was one incessant source of annoyance to all parties, especially to the superintendents, who could never secure attention beyond the moment of their immediate presence.

It was at first superseded by task-work; this was better, inasmuch as a moderate quantity of work was secured: the limits of exertion being known,[2] the prisoners worked with greater activity. But still, in certain descriptions of work, such as building and stone-cutting, it was scarcely possible to decide whether the day's work was done or not. A large block of stone, that required the labour of a week to complete it, was not to be even roughed out in a day or two. In like manner, every little portion of masonry could neither be measured every day without improper waste of the superintendents' time, nor without the errors naturally produced by that sort of accumulation in detail, instead of

[2] See Note 14, and p. 95, vol. iii. Major H. D. Jones on the Defence of Cadiz.

adopting the more simple and accurate mode of taking the aggregate of a month's work at a time.

Finally, the three systems of day, task, and piece-work, were all brought into play by Major (now Lieutenant-Colonel) Blanshard, Royal Engineers. *Day-work*, almost exclusively confined to smiths and carpenters, whose business lying generally in indefinite repairs could not be well tasked, or measured for piece-work, although, when possible, it was so done. *Task-work*, for such objects as wheeling rubbish, where the day's labour was too severe to make it worth the convict's while to prolong it for the trifling extra pay that could be allowed. It was, however, very different with those employed in cutting stone, building, and (where it had been their original occupation) in 'jumping' rock: these men were put on *piece-work*, with the happiest effect; for very slight as their remuneration was, yet, as they were allowed to have no other money than what they earned, in their possession, even the small portion of that trifle that was given them for immediate expenditure, was relatively of great importance to them.

One-third of their earnings was paid them weekly; and they were at liberty to expend this at little shops on board, where ready-made tea, bread and cheese, &c., &c., were allowed to be retailed by well-conducted convicts allowed this privilege of shop-keeping as a premium on good behaviour. The rest was put by as a stock in hand sufficient to maintain them on their liberation for a few weeks. In the mean time, in a distressing climate,[3] and on less than a seaman's rations,[4] they were for years in the constant habit of comparatively willing industry for a very insignificant sum. As far as it might be, the great point

[3] Extract from the letter of a brother officer employed at Bermuda:—"Persons accustomed only to English labour, can hardly understand what an enemy to exertion is the heat of such an enervating climate as that of Bermuda, and particularly with regard to excavators and wheelers. I have seen the trowsers of the men of the 37th Regiment, who worked capitally, as wet from perspiration as if they had been dipped in water. In Gregory's 'Mechanics for Practical Men' you will find the opinions of some French engineers (who superintended works and made experiments on animal strength) on this point."

[4] It was a common error to suppose these men were on a full seaman's rations: they had, each convict, per week,

	lbs.	oz.
Biscuit and Bread	7	0
Cocoa	0	7
Sugar	0	7

was thus gained, not of a disgraceful system of vindictive justice, but of that more enlightened one, whose object is chiefly the reformation of the unhappy subjects themselves; their labour, in the mean time, *far more than reimbursing Government* for the expenses of their punishment. In addition to this, the work advanced with far greater speed; it was also less expensive, especially in masonry, where a reduced rate was allowed for the extra work of the masons' labourers: the whole was cheaper, as the same surveillance did for any quantity of work that was done within the day; and the establishment was for a shorter time[5] employed, from the expedition with which matters proceeded from the date of the adoption of the above arrangements, as ordered by the Commanding Engineer.

After I quitted the colony in 1833, one ship was sent down to St. George's. Acting on the experience gained in the course of the three years that had elapsed since the introduction of task and piece-work, the regulations given hereafter were established. With reference to these, I received, in reply to certain questions, the following remarks from the officer to whose letter reference was made before:—

"The value in time of each description of work was at first assigned from our experience with sappers and line working parties, but taking in each case rather low values, to allow for the greater practice the convicts would acquire; but it was soon found necessary to diminish even these values, and you have the first and second set sent you accordingly.

"The only system we adopted was that of piece-work, or, as it may be termed, 'contract work,' in which *we* fixed the terms. The men were obliged

	lbs.	oz.
Salt Pork	2	0
Fresh Beef	2	4
Vegetables	1	8
Salt	0	3
Peas	2 pints.	
Rum	7 gills.	

As a body, I have never seen men in finer *working condition*. They were well clothed, well fed, and, when they deserved it, well flogged. Latterly, this last disappeared in a great degree with the necessity for it.

[5] This part of the argument is departmental, as giving a reason why it is advantageous for the Ordnance to adopt the system.

to stay on the works[6] during the whole of the working hours; they had no fixed tasks, and consequently had no option, when completed, as to whether they would go on board or not. If the work fell short of that required, or if it exceeded it, the payment was in proportion.

"They generally earned about $1\frac{1}{3}$ day per day, though this is merely given on judgment, as I have no memoranda. Expert masons occasionally made double time. We never had to complain of want of exertion, and the wheelers were never out of a trot the whole day. The excavators worked in gangs at large portions of work sufficient to keep them employed for seven or eight days; they kept one another at work, and we never had occasion to speak to them."

The following is a specimen of a year's work at Ireland Island, shortly after the introduction of piece-work:—

Taking the working year in Bermuda at 300 days.

			Average of daily parties.	
				Men.
Excavation in rock, solid	cubic yards	34447	about	20
Removal of do. reduced to rubbish (or × $\frac{5}{3}$), at an average of, say 2 runs, of 30 yds. each	,,	57412	,,	140
Scarping	superficial feet	54792	,,	12
Ashlar, (1 bed and 1 face measured,) chisel and point	,,	178019	,,	43
Do. plate-saw	,,	2409	,,	3
Do. cross-cut saw and knobbling	,,	48636	,,	10
Lime	bushels	27523	,,	13
Building	cubic yards	10093	{including mortar, but not truck parties,}	60

General Service.

		Days of 1 Man.	
Unloading ships and boats.	Coals	1681	
	Lumber	243	
	Bricks	2016	
	Other stores	267	
		4207	4207

[6] This was a change in the Ireland Island practice, where, however, from the nature of the rock, this change would have been inapplicable. At that place, when the men on task had done their day's work, they were allowed to return to their ships.

Brought forward	4207	
Sand parties in the flats (boats) raising at that time on the north side of the island	3371	
Building a landing quay	370	
Smiths	3106	124
Carpenters	5180	
Truck parties, chiefly attached to Masons for delivery of materials	12000	
Attending boats (before the ships were alongside the breakwater)	6600	
Attending horses and carts	600	
Attending tool-sheds, &c. &c.	1800	
	300) 37234	
	say 124	425 Men total.

All that has preceded, and all that will follow, refers to convicts stationed in small islands remote from continents, from whence escape was very difficult, and where, at the end of each forenoon and afternoon, they were taken back to their prison-ships. The difficulties under other circumstances must be far greater.

In conclusion, with reference to convicts, it is well known to military men how large a proportion of crime in the army arises from drunkenness. Situated as the convicts were, this was rarely practicable under their vigilant officers, Lieutenant Hire, R. N., and Mr. Holliday: from this, and the certainty of prompt punishment, we had as little trouble with them as with soldiers. Few systems have ever worked more admirably than that conducted by Mr. Capper under the instructions of Sir Robert Peel, dated 20th October, 1823.

The sappers were the only troops employed on the works at Ireland Island, but at St. George's, they, and parties from the line, worked extensively in concert.

Slave labour was used for a short time, but was soon given up as altogether unsatisfactory. We had it, however, in 1831, at Hamilton, whilst erecting temporary barracks, and when no other could readily have been made available. Slaves must, if possible, never be trusted with day-work, and, naturally enough, require as keen superintendence as convicts.

PART I.

SECTION I.—*Data for computing the Tables of Prices and Tools, &c., &c., for all Convict Work on Task.*

INDEX.

Works.	*Reference to data.*	*Subjects of the data.*	*Whence obtained.*
EXCAVATION.	I. *a.*	Proportion of portfires to powder.	Own record (after this expressed by N.) of expenditure of 5000 lbs. of powder.
Ditch-w[k] *with* blasting.	„ *b.*	Quantity of powder required to excavate a given mass of rock when no tamping is used.	N. Excavation of 6260 cubic yards of rock.
	„ *b.*	Do. when tamping is used.	N. Excavation of 4600 cubic yards of rock.
	„ *c.*	Jumpers' work per day; rock excavated when on task.	N. Excavation of 8765 cubic yards of rock.
	„ *d.*	Do. depth of hole jumped, on piece-work.	N. 1326 days' work of 1 man.
Ditch-work *without* blasting by pick-work. St. George's soft rock.	II. *a.*	Prices established on the works at St. George's for piece-work.	Order book, &c.
	„	Days' work of sapper or line accordingly.	St. George's.
	„ *b.*	Days' work of sapper or line on task.	Order book, &c.
Driving gallery by blasting and pick-work, medium and hard rock at Ireland Island.	III. *a.*	Days' work of a convict on day-work.	N. Excavation of 3412 cubic feet.
	„ *b.*	Possible quantity of powder in such work per cubic yard.	Ditto.
Driving galleries or sinking shafts *without* blast[g]; by piece-work; St. George's soft rock.	IV. *a.*	Prices established on the works at St. George's for piece-work.	Order book, &c.
	„ *b.* to *f.*	Sapper (with line labour) on piece-work, quantity per day.	Record of 787 cubic yards in galleries & chambers, shafts, &c.; St. George's measuring book.
	V. *a.*	Comparison of the heaped and stricken bushels.	N.
	„ *b.*	Bulk gained by stone when broken into ordinary sized fragments for made ground.	N.
	„ *b'.*	Do. very small fragments.	N.
	„ *c.*	Weights of rubbish.	N.
Wheeling rubbish.	„ *d.*	Days' task of a navigator.	N.
	„ *e.*	Dock-yard barrow-loads and their convicts tasks.	N.
	„ *f.*	Do. do. R. E. department on task.	Order book, and N.

Works.	*Reference to data.*	*Subjects of the data.*	*Whence obtained.*
Excavation.	V. *g.*	Dock-yard barrow-loads, R. E. department on piece-w^{k}.	N.
	,, *h.*	Railroad waggon load.	N.
	,, *i.*	Quantity of water absorbed by the softer stone.	Lieut. Harness, R. E.
	,, *j.*	Duration of barrows and wheeling plank.	Foreman of the Breakwater quarries, Plymouth.
Scarping.	VI. *a. b.*	Days' work of convict on day-work.	N. 6718 superficial feet.
	,, *c. c'. c''.*	Do. on piece-work.	N. 14100 superficial feet.
Cutting Stone.	VII. *a.*	Days' work of a convict on day-work.	N. work of 125 men for 37 days.
	,, *b.*	Do. civilian, task.	S. W. Smith, Resident Admiralty Civil Engineer.
Common ashlar and coping, by chisel and point.	,, *c. c'.*	Do. sapper on piece-w^{k} and coping.	N. 4200 superficial feet.
	,, *d.*	Do. slave* do.	Alexander Swan, a slave.
	,, *e.*	Do. convict do. old regulation.	N. 94485 feet superf^{l} on face.
	,, *f.*	Do. do. do. new regulation.	N. 2980 feet superf^{l} on face.
Ashlar by plate-saw.	VIII. *a.*	Days' work of convict on day-work.	N.
	,, *b.*	Do. do. on piece-work.	N. 4244 feet superf^{l} of cut.
	IX. *a.*	Quantity by convicts on day-work.	N.
	,, *b.*	Do. sapper on task.	Order book.
	,, *c.*	Do. line do.	Do. and Lieut. Harness.
Ashlar by cross-cut	,, *d.*	Do. sapper on piece-work.	Armstrong, Acting Overseer.
	,, *e.*	Do. line do.	Order book and L^{t}. Harness.
	,, *f.*	Do. slave do.	Dr. Tucker and other slave owners and contractors.
	,, *g.*	Do. convict do.	N. 11915 feet superf^{l} on face.
	X. *a.*	Quantity by sappers on piece-work.	N. 1330 feet superf^{l} on face.
Knobbling.	,, *b.*	Do. convicts do.	N. 45808 feet superf^{l} on face.
Ash^{r} in arch-stones,	XI. *a. a'.*	Quantity by sappers on piece-work.	N. 1252 cubic feet.
Raising and cutting Bermuda slating.	XII. *a.*	Quantity raised and trimmed by sappers on task.	Order book and L^{t}. Harness.
	,, *b.*	Do. by black on piece-work.	Dr. Tucker and other slave owners, &c.
Building.	XIII. *a.*	Specific gravities of the stone.	Lieut. Harness and N.
	,, *b. c.*	Effect of calcination on bulk & weight.	Lieut. Harness.
	,, *c.*	Weight and bulk gained by slaking soft stone lime.	Lieut. Harness.
Burning lime.	,, *d. d'*	Bulk gained by slaking hard stone lime.	Lieut. Harness and N.
	,, *g. g'. g''.*	Proportions of coal to lime in hard stone.	N. 96510 bushels of quick-lime.
	h	Do. of soft stone.	N. 9307 bushels of quick-lime.

* The words black, or slave, are here used indifferently.

Works.	*Reference to data.*	*Subjects of the data.*	*Whence obtained.*
BUILDING.	XIV. *a.*	Bulk given by different proportions of lime and sand.	N.
	,, *a'.*	Strengths of mortars made of different proportions of lime and sand.	N.
Making mortar.	,, *b.*	Quantity of mortar made by a horse pugmill per day.	N.
		Do. by a hand pugmill.	N.
Masonry in escarps and coping,—massive work.	XV. *a.*	Bulk of mortar to stone in masonry.	N. 129 cubic yards.
	,, *b.*	Quantity by sappers on day-work.	N. from Mennon, Overseer of Works; 1327 cubic yards.
	,, *c.*	Do. convict do.	N.
	,, *d.* to *d''''.*	Do. do. on piece-work.	N. 12021 cubic yards.
Masonry in retaining and thin walls.	XVI. *a.*	Quantity by convicts on day-work.	N. from S. W. Smith's books; 1573 cubic yards.
	,, *b.*	Do. civilian task.	Armstrong, Ov. W.
	,, *c.*	Do. black do.	N. temp^y barr^ks at Hamilton.
	,, *d.*	Do. convict on piece-work.	N. 30 cubic yards.
	,, *e.*	Do. sapper do.	Armstrong, Ov. W.
	,, *f.*	Do. black do.	N. temp^y barr^ks at Hamilton.
Masonry in casemate arches.	XVII. *a.*	Quantity by sappers, piece-work.	N. and from Armstrong, Casemate of bastion, E. &c. &c.
Brick-work in casemate arches.	XVIII. *a.*	Quantity by sappers, piece-work.	N. Casemate arches on the Land-front and the Magazine.
Roofing with Bermuda slate.	XIX. *a.* & *b.*	Quantity of slates and mortar per C.	N. temp^y barr^ks at Hamilton.
	,, *c.*	Weight of 1 C. of roofing.	Lieut. Harness.
	,, *d.*	Quantity by sapper on task.	Order book.
	,, *e e'.*	Do. black do.	N. temp^y barr^ks at Hamilton, &c.
Shingling.	XX *a.*	Sorts, durabilities, prices, modes of demand, and lap; days' work and nails required.	Foreman of carpenters at the dock-yard.
	,, *b.*	Boston chips; quantity req^d per C.	N. from a house built at Ireland.
	,, *c.*	Nails, &c.	
	,, *d.*	Days' work for sapper on task.	
Cementing.	XXI. *a.*	Quantity of cement required per C.	N. 850 superficial feet.
	,, *b.*	Proper task for a plasterer.	N. and Armstrong.

The remaining Royal Engineer department items were all collected by myself, to satisfy different questions that suggested themselves from time to time; but not being used in the computations for prices, are not referred to like the preceding.

DIVING BELL.

Works.	*Subjects of the data.*	*Whence obtained.*		
Building stage.	Soil, silt and sand.	Run of 536 ft.	Mr. S. W. Smith.	
Excavation.	In chalky silt.	2254	cub. ft.	do.
	Coral reef and rock.	7490	do.	do.
	Silt, reef, and rock.	11890	do.	do.
Building in wharf-walls.	Mixed example, excavation and building.	27797	do.	do.
	Building only; cement, and account of gross and net time.	155163	do.	do.
	Expense of such work per cubic yard.[9]			
	Rates of working different bells under the same circumstances.	41123	do.	do.
Flat stone pavement.	For a mast and boat slip; quantity of cement and time.	10336	do.	do.

Task and Piece-work Regulations for Convicts at Ireland Island, 23rd *May,* 1832. *Per diem. By Major Tylden, based on the original orders of Major Blanshard,* 1830.

Jumping rock.	Depth of hole, 12 feet hard rock, 14 feet medium, 16 feet soft. After 10 feet deep, in one hole, each foot to count for 2, or an extra man allowed.—N. B. It is nearly as bad to work medium and soft, as hard, from the increased trouble in clearing.
Wheeling rubbish.	300 *full* bushel barrows 30 yards; from a level ground to a slope of 5° and 224, from 5° to 15° per diem.
Scarping.	6 feet superficial, medium rock, when blown to within 18 inches of the scarp; of more than 18 inches, a jumper to be allowed.
Cutting stone. Common ashlar.	Stretchers, 3 feet on face; but if a stone have more than a 3-feet bed, to be called a header; in which case 1 joint and 1 face to be measured, provided height : bed : : 1 : 2. hard rock.[10]
Cutting stone. Plate saw.	1¼ feet, cut superficial, hard stone, per man. 1½ feet, do. medium, do.
Cross-cut saw.	10 feet superficial on face.
Knobbling.	6 feet hard; 8 feet medium; 10 feet soft on face.
Building.	Masonry, coping, 1 builder, 6 labourers, 4½ cubic yards. Escarp, 2 builders, 10 labourers, 4 cubic yards.—Materials delivered, but including party at the mortar mill. Brick-work in arches, 2 builders, 2 labourers, 3 cubic yards.—Materials delivered. For extra work, the masons to receive full proportion. Do. labourers do. half.

[9] Altered in some respects from the amount as given by Mr. Smith, as I have substituted the Ordnance price of cement for that charged to the Admiralty.

[10] Sappers were allowed 3*d.* per foot superficial on face for common ashlar; 3½*d.* per foot for coping; and 4*d.* per cubic foot for arch stones.

Royal Engineer Department Regulations for Convicts at St. George's.

The proportions established as equivalent to a day's work, on the first removal of convicts from Ireland Island to St. George's, 1st October, 1833, were founded on our experience of the labour of sappers and line working parties; and dependence on the expertness the convicts would acquire by *being always employed at the same description of work.* Hence, the largest scale of tasks we had ever obtained was adopted; but in May, 1834, a much higher rate became necessary.

With respect to the rock in which our excavations were carried on, and of which our ashlar was made, it may be stated, that as a soft calcareous sandstone, its specific gravity averages 1476; that it can absorb ⅖ of its bulk of water; and that its resistance to a crushing force is about ¼ that of brick, or about 280 lbs. per square inch. The hardest stone at the ferry, where lime was at first made, has a specific gravity of 2630, and takes up no perceptible quantity of water.

With reference to the Commanding Royal Engineer's orders, 1st Oct. 1833.

Excavation. Day's work for 1 man, digging and throwing out.

	Open excavation.	Shafts or galleries.	Trenches less than 10 feet wide.
Sand or mould .	4 cubic yards.		4 cubic yards.
Soft rock . . .	3 do.	1½ cubic yard.	2¼ do.
Hard rock . .	2 do.	1 do.	1½ do.
Very hard . .	1¼ do.	½ do.	¾ do.

By the Commanding Royal Engineer's orders, 14th May, 1834, the task of "sand or mould" was increased to 5 cubic yards; and the allowance for narrow trenches restricted to those under 7 feet in width.

Removing rubbish. Day's work per man, not including filling.

In a tip-cart on a level railway	40 cub. yds.	moved 50 yds.
In a wheelbarrow on open level ground or down hill	10 do.	
Do. do. in galleries	10 do.	30

Up hill, a rise of 6 inches counted for a yard of distance in reducing the above.

No allowance for removal, unless the distance exceeded 4 yards from the place of excavation.

Cutting stone. No stone by cross-cut saw was received of less height than 6 inches, or of more than 11 inches; or that was not exactly either 6, 7, 8, 9, 10, or 11 inches on that dimension; or that was not true to the square; or of less breadth than 15 inches, or

Cutting stone. more than 30 inches; of less length than 12 inches, or more than 30 inches; and $\frac{1}{4}$ of the quantity was required to be fully 2 feet in the bed; and $\frac{2}{3}$ to exceed 7 inches in height. The softness of the stone, at that time, was the cause of using such small stuff: the quarry improved afterwards.

Day's work for 1 pair of sawyers.

Ashlar, prepared as above, with 1 face, 2 beds, and 2 joints	30 running feet.	
	40*	do.
Do. with 2 faces, and of assigned breadth, not exceeding 18 in.	20	do.
	30*	do.
Arch-stone or coping. 1 foot in height	15	do.
	30*	do.
do.	20*	do.
	10	do.
	15*	do.
3 do.	8	do.
	14*	d
4 do.	6	do.
	8*	do.
9-inch cordon, sawn and prepared	28*	do.
Quarrying and cutting, with 2 beds, 2 joints, and 1 face, per man	7½	do.

The numbers with asterisks show the changes in the original order, by that of 14th May, 1834.

Bermuda slate. The blocks having been first prepared and allowed for as ashlar, with 2 faces, 18 in. × 18 in., 80 slates were considered as a day's work for 1 pair of sawyers.

Masonry. Each builder was allowed 3 constant labourers, to assist and supply with all materials; on some occasions 4 were given.

Day's work for each builder.

Solid measurement. 2½ cubic yards, and 1 day's work allowed for
10 superficial yards of straight facing.
5 do. circular do.

Arches were paid for at 1¼ yard solid for 1 day's work, adding the allowance for circular facing.

Mortar parties were not included in the above; the 'chain-gangs' (or those too heavily ironed for other work) were thus employed at the pugmill.

DATA.

Memorandum.—The nominal length of a convict's day's work at Ireland Island, Bermuda, is 8 hours; in reality, allowing for broken time, not more than 7½.—Thermometer, from 52° in the winter to 86° in the summer, in the shade, and far more of the latter than of the former.

EXCAVATION.

The very variable nature of the rock, and consequently fluctuating expense of working it, is well exhibited in the comparison of the results of the four following records of excavation, premising that the general distribution of a quarry party was :—

1 Sapper, superintending.

1 Ganger (or well-behaved convict in charge of the rest, but not working).

Four sets, consisting each of

1 Jumper.

3 Clearers.

1 Filler.

1 Run of barrows per jumper at most.

1st. In the ditch of the face of the right half-bastion of the Land-front, 2115 cubic yards of a very irregular rock; sometimes hard, sometimes soft, and much mixed with a sandy bed. Excavated between April 18th and Nov. 9th, 1829. Net working days, 164.

2nd. In the ditch of the face of the left half-bastion of the Land-front, containing 4150 cubic yards; traversed by beds of red earth and rubble, but not quite so bad as No. 1. From 3rd Nov. 1829, to 23rd April, 1831. Net working days, 381.

3rd. A continuation of No. 2, but using dry sand tamping (no tamping having been previously used); containing 2500 cubic yards, of a somewhat sounder rock than No. 2. From 24th April, 1831, to 21st April, 1832. Net working days, 291½.

4th. The ditch of the Land-front couvreport; a hard rock in a ditch only 24 feet broad, where large blasts could not have been used without injury to the scarps. Net working days, 274.

By comparing these:

Net days, 1110½. Cubic yards excavated, 10915. Powder, 19505 lbs.

In blasting with dry sand tamping 1052 portfire drops were expended on 1290 lbs. of powder; say $\frac{1052}{15} = 70$ portfires, or about 1 : 18 lbs. of powder. By another record 2704 were expended on 3800 lbs.; say $\frac{2764}{15} = 184$, or about 1 : 21 lbs. of powder.

Hence say, 1 portfire : 20 lbs. of powder.

1. *b.* Powder per cubic yard, lbs. average.

Without tamping.	With dry sand tamping.[11]
Nos. 1 and 2, average 2·035.	Nos. 3 and 4, average 1·36.

2·035 : 1·36 : : 1 : 61, or reduction by using sand tamping, say $\frac{2}{5}$.

Cubic yards excavated per jumper per day. The jumper on task, the rest partly on day-work.

5·78 5·7 5·5

c. Average, say 5·6 cubic yards per jumper per day.

The purposes for which the stone was required, and the places to which it was taken, were so uncertain, that piece-work could never have been given to the whole party. Hence, as the jumpers and wheelers were tasked, though no very defined limits could be given to the clearers and fillers, it was considered sufficient that they should always keep the quarry in such a state of forwardness as to allow the remainder to work without interruption.

Record of jumping, on piece-work, from 1st June, 1830, to 1st June, 1831.

Rock in general hard; on Curtain G. H.

Men's days' work . . . 782

Total gain in days . . . 544½

Then $\frac{544\frac{1}{2}}{782} \times 14 = 9{\cdot}74$ feet average gain per man per day.

14· task per day.

23·74 average total of the day's work.

II. Prices established for piece-work.

Ditch work, &c., without blasting, by pickwork, St. George's; soft rock, military labour.

Sand that scarcely held together .	3*d.* per cubic yard, and all wheeling under 50 yards : 1*d.* for each run extra.			
,, *a.* Soft stone	4*d.*	do.	do.	do.
Stone equal to about Bath stone .	8*d.* to 11*d.*	do.	do.	do.

The average earning at this rate was from 1*s.* 8*d.* to 1*s.* 10*d.* per diem.

[11] Introduced by Major Tylden, Royal Engineers. Still this consumption of powder is enormous, but it could not be helped, as the time in which it was possible to blast was very limited. In the blue limestone quarries at Devonport and Plymouth 4 lbs. per load of 16 tons or about 7 cubic yards is allowed, though they do not work so fast. When what is virtually water tamping is used, as hereafter shown, it takes about ⅓ lb. per cubic yard.

In the large excavation for soft stone for the barracks inside Retreat Hill redoubt, at the commencement the task was 2 cubic yards per man per day for sappers and

II. *b.* line, at $9\frac{1}{2}$ hours net time. Being left to their own arrangements, a party of 10 would undertake 20 cubic yards; 5 to raise stone, 5 to break, fill, and carry away for one run. When the material was favourable they would do their task in 7 hours, net time, but not before they had been several weeks so engaged, without being allowed to undertake any other work, and as much as possible freed from regimental duties.

III. Driving gallery by blasting and pickwork, in medium and hard rock, Ireland: convict day-work.

Figs. 1, 2.

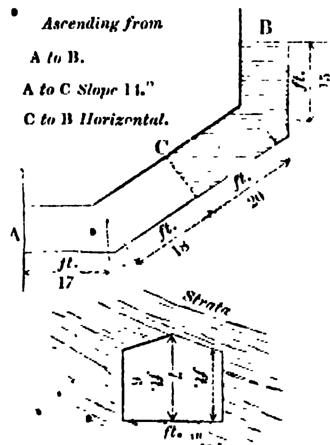
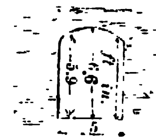


Fig. 3.



Average strength of the gang, 5·2 convicts, and 1 sapper in charge.
Net time 68 days.

Quantity excavated = 3412 cubic feet, or 126 cubic yards. Powder expended, 630 lbs.

a. Then $\frac{3412 \text{ cubic feet}}{68 \text{ days}} = 50\cdot2$ cubic feet per day, or about 9 cubic feet per day per man.

b. And $\frac{3412 \text{ cubic feet}}{630 \text{ lbs.}} = 5\cdot41$ cubic feet for each 1 lb. of powder, or say 5 lbs. per cubic yard.

The slope rises from A to C at an average of 14°; from C to B the gallery is horizontal. The work began at A, and having proceeded 50 feet, it was found too severe for the heat of the weather and the confined air; the gallery was recommenced from B, where the rock was much harder than below. Two convicts at a time worked in driving; each party relieved the other by changing to wheeling the rubbish to the mouth.

Prices established for piece-work.

IV. Driving galleries and sinking shafts, by pickwork *without* blasting, in soft rock. St. George's: military labour, piece-work.

Sand that scarcely held together .	8*d.* per cubic yard, including all wheeling under 30 yards. 1*d.* per run extra.
Soft stone, about equal to Bath stone	10*d.* to 1*s.* 8*d.* do. do. do.

" *a.* The average earning at this work was about 1*s.* 5*d.* per diem of $9\frac{1}{2}$ hours net.

From some of the monthly work bills for 1830, 1831, and 1832, for work done in galleries at Retreat Hill, party consisting of 2 sappers (regular miners from the coal districts), and 1 line labourer to wheel, whom they paid:

" *b.* A record of 533 cubic yards excavated gives from 30 cubic feet at 1*s.* 6*d.* per yard to 23 cubic feet at 2*s.* per miner per day.

Galleries of the reverse fires at south-east end of this work.

Total length, 95 feet.

2 sappers and 1 line as above, 42 days net.

" *c.* $\frac{95}{42}$ feet run = about $2\frac{1}{4}$ feet run per day, or say 34 cubic feet per miner per day, but the preceding is safer.

In a reverse fire 11 feet × 12 feet × 10 = 1320 cubic feet.
And a gallery leading to it 6 × 8 × 5 = 240 "

1560

$44\frac{1}{2}$ days of 1 sapper, and 42 of a line labourer, at 10*d.*; allowed 2*s.* per cubic yard, to include candles and 1 line labourer.

d. $\frac{1560}{44 \cdot 5}$ = 35 cubic feet per miner per diem.

In this case there was but little gallery work, and much chamber; there were also 2 runs, beside the above, of line soldiers, on day-work at 10*d.*, at about 75 yards per run.

e. Excavating a lime-kiln at Retreat Hill, $25\frac{1}{4}$ cubic yards; took $27\frac{1}{8}$ days of a sapper at 1*s.* 6*d.* per yard, or not quite 25 cubic feet per day.

f. Well at Retreat Hill, equal to soft Bath stone.

This well was 5 feet in diameter at the mouth, which was gradually reduced to 4 feet at the depth of 20 feet. This last remained unaltered for the rest of the depth = 113 feet 6 inches. The water stood at best about 4 feet high at the bottom, depending on the rise or fall of the tide, which, acting through this very porous rock, bore the fresh water above it.

Commenced September, 1831, by 2 sappers at 2*s.* per cubic yard; at this rate they worked for 33 feet 6 inches deep, but it scarcely paid them; in October and November they commenced afresh, at 1*s.* 6*d.* per running foot in depth, and increased 1*d.* for every 10 feet deep until they reached water, when the rate was increased.

119 days of a miner; sunk 133 feet 6 inches.
Total content = 1745 cubic feet = 15 cubic feet per miner per diem.
Total days net = 119.

V. Wheeling rubbish.

,, *a.* Six heaped bushels of dry sand (the measure being the usual cylindrical one, 8 inches deep) gave $7\frac{3}{4}$ stricken bushels; hence in this case, the heaped bushel : stricken bushel :: $7\frac{3}{4}$: 6 :: 31 : 24.

To ascertain what bulk stone gained by being broken into such fragments as are usually carried in wheelbarrows for glacis, made ground, &c., a flat block of stone,
,, *b.* containing 56·8 cubic feet, was broken into such pieces, weighing, say 12 lbs. and less, and was then piled up very exactly on 2 railroad waggons; one load was complete, as 6 feet × 3 feet × 3 feet; the other 6 feet × 3 feet × 2 feet 2 inches. Total, 93 cubic feet of rubbish obtained.

Then 56·8 : 93 :: 1 : $1\frac{2}{3}$ nearly. Hence the gain in bulk was $\frac{2}{3}$ of the original.

To try how far this rule applied to very small fragments of, say about 3 ounces, a piece of ashlar, containing 15·38 cubic feet, gave 21 stricken bushels, or 26·13 cubic feet.

$$\begin{array}{r} 26{\cdot}13 \\ \text{Dedt. } 15{\cdot}38 \\ \hline 10{\cdot}75 \end{array} \qquad \text{And } \frac{10{\cdot}75}{15{\cdot}38} = \frac{2}{3} \text{ nearly,}$$

as before. This was tried a second time, with the same result.

Ireland.

1 bushel of common earth and stone rubbish weighed 90 lbs.
1 bushel of common stone rubbish 100

Hence a cubic foot of stone rubbish would have weighed about 80 lbs.; and this agrees very well with what would be given by XIII. *a.*, where the average stone was about 138 lbs. per cubic foot; *i. e.* $\frac{138 \times 3}{5} = 83$ lbs., supposing that it be reduced to rubbish, and $\frac{3}{5}$ taken for the quantity in a cubic foot measure.

d. Navigators on task-work.

During $9\frac{1}{2}$ hours on the level top of the breakwater, each filled, and ran, 19 *piled* barrows of stone rubbish 30 yards per hour; and 4 sets $= 4 \times 19 = 76$ barrows so *piled* were taken up and wheeled by a fifth man 30 yards.

Then $76 \times \frac{3}{4}$ cubic foot $\times \frac{2}{3}$ rub. rock $\times \frac{19}{2}$ hours $= 40$ cubic yards of solid rock, 30 yards per man per day; or 20 cubic yards of solid rock, 60 yards per man per day.

e. To ascertain the loads carried by convicts on the larger barrows used on the Admiralty works, I measured 6 of them that had been just filled with their usual load of earth and stone rubbish.

They measured 8 stricken bushels, or $\frac{8}{6} = 1\frac{1}{3}$ bushel per barrow; but with earth only, they contained only 1 bushel.

Each of these barrows may be estimated at 1 cubic foot of solid rock when on convict task-work, of 180 barrows on a level run of 60 yards per day, as given in the dock-yard. It requires careful superintendence, however, to see that they do carry this cubic foot.

f. To obtain the same with reference to the smaller barrow used by the R. E. department, *calculated* to hold about $\frac{3}{4}$ of the above, 2088 barrow-loads were carefully deposited as a square prism, 20 feet broad $\times$ 20 feet long $\times$ 6 feet high $= 89$ cubic yards. Say the proportion to be 2100 barrow-loads : 90 cubic yards. Then $\frac{2100}{90}$ $= 23\frac{1}{3}$ barrows per cubic yard of rubbish.

1 cubic yard of rubbish contains $21\frac{3}{4}$ stricken bushels. Then $\frac{23\frac{1}{3} \text{ barrows}}{21\frac{3}{4} \text{ bushels}} = 1{\cdot}072$ stricken bushel per barrow.

And $1{\cdot}072 \times 100$ lbs. $= 107$ lbs., the average weight of the R. E. department barrow.

g. Each of these barrows may be estimated at $\frac{3}{4}$ cubic foot of solid rock, when convict task; but to see what might be done when the convict *wished* to work, the same heap was reserved for the next Government freight-ship that might be allowed the occasional indulgence of ballast from the works.

This the prisoners were permitted to do *after they had completed their days' task.* The heap was built in 2088 barrow-loads in task-work, and taken down in 1390 barrow-loads in piece-work.

Hence, as the heap was low, and the difference between building up and taking down inconsiderable, the effects of piece-work : task-work :: 2088 : 1390, or as $1\frac{1}{2} : 1$ nearly; and if the lengths of the runs be considered, or 105 : 90, it will be $1\frac{3}{4} : 1$, and this too at the close of a regular day's work; (but they could never continue at this rate without change of diet as well as pay.)

In this case their pay was higher; for the 35 men who undertook the work were to be allowed £3 for so doing, and having worked 3 evenings, completed it, except a small residue of 12 barrows: they appeared to be rather discouraged and indifferent

towards the end. Hence it appears to be about the minimum necessary to stimulate a convict to wheel rubbish on piece-work, or $\frac{£3}{3 \times 35}$ = not quite 7*d.* per man per day, provided they have no other money.

The total distance between the heap and the vessel was 420 feet: out of the 35 men, on their own arrangement, 16 told themselves off as wheelers in 4 level runs of 105 feet each, the remainder as gangers, fillers, and the stowing party on board.

V. *h.* Referring to V. *b.*; such a waggon-load could not be relied on in practice: 35 cubic feet per waggon load is as much as would be safe in estimate.

,, *i.* See V. *b.* and V. *b'.* There is a singular coincidence between the bulk thus gained and the quantity absorbed by the most porous description of Bermuda stone; by the experiments of Lieut. Harness, R. E., to ascertain the additional load on a roof of such drip-stone material in rainy weather, he found that the quantity of water was $\frac{2}{5}$ of the bulk of the stone.

,, *j.* From inquiries that I have made amongst experienced persons, a well-built navigator barrow, guarded with iron straps, may be expected to last 6 months without repairs; and, if duly watched in this respect, will stand 12 months of severe work. In earth-work double the time may be allowed.

2-inch pitch pine plank (wheeling) may be reckoned upon for at least 15 months with the heaviest work, if bolted, and if possible, hooped at the ends. Navigators and embankment men will rarely however permit these hoops, as occasioning a jarring that is perceptible at the end of the heavy day's work they execute. Their modes of managing themselves are curious.

VI. Scarping.

This work was performed entirely by convicts.

Day-work. Rock hard, and full of troublesome fissures.

Net 173 days.

In this time, with 1321 days of 1 convict, they scarped a space of 193 feet × 26 feet = 5018 superficial feet.

,, *a.* Then $\frac{5018}{1321} = 3{\cdot}79$ superficial feet per man per diem.

At the rear of the rampart of curtain G. H.; rock hard, but sound, 444 days' work produced 1700 superficial feet.

,, *b.* Hence $\frac{1700}{444} = 3{\cdot}82$ superficial feet per man per day.

So that $3\frac{3}{4}$ feet at least, on day-work, may be expected per man; and as this bore a fair proportion to the ashlar, 4 feet was at first given, from the above data, as the daily task on the R. E. department works; the surplus to be paid for in proportion.

VI. *c*. The consequence was, that at least $5\frac{1}{2}$ feet superficial per day was completed in the first month.

As the men acquired skill and habits of industry they did far more, and notwithstanding the task was increased to 6 feet superficial, they performed as follows:

4080 superficial feet in 300 days' work of 1 convict.

,, *c'*. Hence $\frac{4080}{300} = 13{\cdot}6$ feet superficial per man per day, at an average of 4 months.

As further skill was acquired:

,, *c''*. 10020 superficial feet ÷ 517 days = $19\frac{1}{3}$ feet per man per day, in hard and very sound rock between bastion H. and the Land-front. More would have been completed, but that one portion was done over again at the men's expense, having been ill executed.

VII. Chisel and point ashlar, common, and coping.

,, *a*. Day-work, convict only. From a record kept of the labour of 125 men for 37 weeks, this system gave no more than $1\frac{1}{8}$ foot superficial on face, hard stone, per man per day!

Task-work, convict only. See Task Regulations.

,, *b*. Civilians in dock-yard. 3 feet superficial on face; best work in house-fronts.

,, *c*. Piece-work, sapper. 2 of our best workmen and steadiest men did $330\frac{1}{2}$ feet superficial of coping (measuring only what is shown) in 38 days' work of 1 man, or 8·7 superficial feet coping per sapper per day at best.

,, *c'*. Sapper, common ashlar and coping. 3869 superficial feet on face in $476\frac{1}{2}$ days' work, or 8·11 feet superficial on face per sapper per day; but this is rather lower than it should have been, as it includes some coping at $3\frac{1}{2}$*d*. per foot. Common ashlar at 3*d*.

,, *d*. Black. In their coarse way, black stone-masons will work 5 feet superficial on face, in the long day of 10 hours, at 1*s*. per foot at the quarry.

,, *e*. Convict, on old regulations of 1830, 6 feet per diem of 1 bed and 1 face, measured. Many of the convicts near the expiration of their sentences.

Regular work in days	11400
Time gained in days	14846

Hence $\frac{14846 \times 6}{11400} = 7{\cdot}81$ superficial feet average gain per man per day.

6·0 regular task.

13·81 average of total days' work, per man, of common ashlar.

Assuming the ratio of bed : face to have been on the whole as 5 : 3

$\frac{13{\cdot}81 \times 3}{8} = 5{\cdot}18$; say 5 feet on face per man per day.

,, *f*. Convict, on regulations of 23rd May, 1832, 3 feet on face only.

$\frac{2980 \text{ feet superficial}}{462 \text{ days}} = 6{\cdot}45$ feet on face, per man per day, of common ashlar.

VIII. Ashlar by plate-saw.

,, *a.* Convict only, day-work. The most industrious convict never did more than $8\frac{1}{2}$ feet superficial of cut in 6 days; then $\frac{8\cdot5}{6} = 1\cdot41$ feet superficial of cut per man: he however worked alone. With another to assist, not more than $\frac{3}{4}$ foot could ever be obtained by *a pair* on day-work. For Task-work, see Regulations.

,, *b.* Record of piece-work.

Regular work in days	591
Time gained in days	549

Then $\frac{549 \times 1\cdot25}{591} = 1\cdot12$ average gain.
1·25 task.

2·37 feet superficial, average daily per man of cut.

By a record kept in January, February, and March, 1833,

,, *b'.* $\frac{\text{2819 feet superficial of cut}}{\text{728 days' work}} = 3\cdot87$ feet superficial of cut per man per day.

IX. Cross-cut saw, soft-stone.

,, *a.* Day-work, convict only, Ireland. 2 pair of convicts cut 56 feet superficial of facing in 6 days, or $\frac{56}{2 \times 2 \times 6} = 2\frac{1}{3}$ feet superficial per man per day!!

,, *b.* Task-work, sapper, at St. George's. 9 feet cubic per day of $9\frac{1}{2}$ hours net; they would sometimes complete it in 6 hours, including raising and trimming.

,, *c.* Task-work, line, at St. George's. 4 feet cubic per day of $9\frac{1}{2}$ hours; these men were not so accustomed to the work as the sappers; they would sometimes take the whole day to complete the task; which however, as in the preceding, required to be nicely finished.

Task-work, convict. See Task Regulations.

,, *d.* Piece-work, sapper. When building the Military Hospital at St. George's they were allowed 2*d.* per foot cubic. The most skilful raised and squared $13\frac{1}{4}$ cubic feet per day: this agrees pretty well with IX. *b.*

,, *e.* Line piece-work Regulations at St. George's.

No stone to contain less than 1 foot cubic, or more[12] than 3 feet, or

Not less than	12 inches—not more than	30	inches	long,
,,	12	,,	24	,,	broad,
,,	6,	,,	11	,,	deep.

[12] From the very soft nature of the material; it varied afterwards so as to allow larger blocks to be built into the work without cracking down the face.

3s. 3d. per cubic yard allowed, and to keep their quarry clear, unless the rock was very sandy. They earned from about 1s. 3d. to 10d. per day, or about from 10 to 7 feet cubic per man per day.

IX. *f.* Piece-work, black. Their work, which is very inferior to that of any other class, from being slaves, varies from 13 feet cubic to 29 feet, depending on the length of the working day, the weather, the skill of the workmen, &c. &c.

	in. in. in.		
The *quarry* prices were in 1833 .	12 × 12 × 18	10 S. $.[13]	per 100.
	6 × 12 × 18	5	,,
	6 × 10 × 18	4	,,
	6 × 8 × 18	3	,,

As soon as ever this stone is received it should be sorted and stacked, and the workmen compelled to take the blocks as they lie in succession, otherwise a heap of this material will be quickly ruined. From its coarse workmanship much time is lost in trimming whilst building. One-fifth waste should be allowed in estimate for common Island stone: if the precaution above mentioned be not taken, it will vary from ¼ to little short of ⅓.

.. *g.* Convict, on piece-work.

Regular work in days 525

Time gained in days 666½

$$\frac{666\frac{1}{2} \times 10}{525} = 12{\cdot}69 \text{ average gain per man per day.}$$

10· task.

22·69 superficial feet on face per man per day.

X. Knobbling. Ireland.

I have no record of this when done by day-work. For task-work, see Task Regulations.

.. *a.* Piece-work, sappers.

Medium stone, $\frac{896 \text{ feet superficial on face}}{46\frac{1}{2} \text{ days' work}} = 19{\cdot}27$ feet per man per day.

Hard stone, $\frac{434 \text{ feet superficial on face}}{72\frac{1}{2} \text{ days' work}} = 6$ feet per man per day.

.. *b.* Piece-work, convict.

Regular work in days 2736

Time gained in days 2990

$$\frac{2990 \times 8}{2736} = 8{\cdot}74 \text{ average gain per man per day.}$$

8· regular task.

16·74 superficial feet on face per man per day.

[13] The Spanish dollar, at about 4s. 2d. sterling.

XI. Arch Stones, &c.

Only done by sappers on piece-work at 4*d.* per foot cube. In order however to make them cautious, the same party is required to build the material, that cuts it. Altogether $4\frac{1}{2}d.$ per cubic foot was allowed for archwork completed.

Archway at main entrance, &c.

„ *a.* $\frac{972 \text{ cubic feet}}{113 \text{ days' work}} = 8{\cdot}6$; say $8\frac{1}{2}$ cubic feet per sapper cut per day.

Archway at Curtain H. I. (harder stone) same men.

„ *a'.* $\frac{280 \text{ cubic feet}}{38\frac{1}{2} \text{ days' work}} = 7{\cdot}27$; say $7\frac{1}{2}$ cubic feet per sapper cut per day.

XII. Raising Bermuda Roofing Slate.

„ *a.* Task, sapper. The soft stone, raised by the line, shaped as a block 4 feet × 1 foot 6 inches × 1 foot 6 inches, gives 40 slates; and to cut these 40 is 1 day's work, after which they are slightly trimmed at 120 per day.

„ *b.* Piece-work, black. 2 blacks will saw 150 per day, if ready-raised and trimmed; 1 will raise and trim 250 per week.

General price at the quarry $. $2\frac{1}{2}$ per 100.

XIII. Burning Lime.

The first 5 data refer to points connected with the bulk, weight, &c., &c., of stone and lime.

„ *a.* Specific gravity of Ireland stone, medium and hard, 5 cubes of stone, 6-inch sides.

	lbs. oz.	lbs. oz.		oz.	
No. 1. from the Redoubt of the Ravelin	8 × 12 11	= 101 8	or	1624	per ft. cube.
2. do. do.	17 11	= 131 8		2104	do.
3. do. do.	19 3	= 153 8		2456	do.
4. Bastion I.	18 12	= 150 0		2400	do.
5. do. H.	19 12	= 158 0		2528	do.
	Average	138 14		2222	do.

The worst of the above was superior as a building material to the best St. George's soft stone; weighing 92 lbs. 8 oz. or 1480 oz.—Lieut. Harness.

b. To ascertain whether bulk was lost or not in burning, six 3-inch cubes of soft stone were passed through the kiln; they came out unaltered in size, but with the loss of about half their weight.—Lieut. Harness.

c. A stricken bushel of St. George's soft stone, broken into fragments, weighed 72 lbs.; when burned, 38 lbs., when slaked, 46 lbs., and giving $1\frac{1}{4}$ bushel; each bushel so slaked in powder weighed $37\frac{1}{2}$ lbs.—Lieut. Harness.

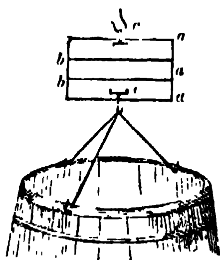
XIII. *d.* A box of 15 inches cube, (containing 66 measures, weighing 14½ oz.) filled with soft-stone lime (quick), gave 5½ inches additional. When filled with the hardest stone quick-lime it expanded, on being slaked, to double the content of the box.—Lieut. Harness.

,, *d'*. Quick-lime at Ireland, from stone not so compact, gave ⅝ additional bulk.

The Bermudians sell their quick-lime at double the price of the slaked lime.

,, *e.* Experiments to ascertain the strengths of mortar, made with different proportions of sand and lime, were made by laying equal quantities by bulk of mortar between equal surfaces, allowing them to dry for 4 months, and then breaking them off by loading the lower brick as in the annexed sketch, by pouring measures of water of known weight into the vessel beneath.

Fig. 4. *Experiments on strength of mortar.*



a bricks.
b mortar.
c cramps.

To insure equal quantities of mortar it was laid on from a mould; to obtain equal surfaces, each sort was tried by six sets of bricks, which gave a result sufficiently near for practical purposes: so that the following is the average from 12 pieces, or 24 surfaces of mortar, with the same length and breadth as a brick.

April, 1833.

2½	bushels of sand	: 1	slacked lime, broke with	105 lbs.
3	do.	: 1	do.	134
3½	do.	: 1	do.	100
4	do.	: 1	do.	112
4½	do.	: 1	do.	80
5	do.	: 1	do.	67
5½	do.	: 1	do.	85
6	do.	: 1	do.	79

Thus the general opinion, that 3 sand : 1 slacked lime is the strongest proportion, appears to be supported. This however should, if possible, be always made the subject of experiment: the fluctuations above shown, and those which occurred in many others of a similar nature which I made, prove that such matters are not to be taken for granted.

These trials would not have been carried so far, but for the assertion of a certain great authority, that "if the particles of sand were only made to adhere by a mere wash of lime, it would be sufficiently strong." This was kept for the conclusion of the experiments, and confirmed the deduction from the above decreasing series, that the

notion was altogether erroneous. It will require much care to enforce the adoption of that proportion of 3 : 1, and can scarcely be carried into execution without a pugmill.

XIII. *f.* In calculations where it is necessary to reduce the bulk of mortar thus made into those of its constituents, sand and lime, it may be considered that the lime and water occupy the interstices; hence the bulk of sand will be the same as that of the mortar. Many experiments were made on this subject. See XIV. *a.*

Proportions of Coal to Lime obtained.

Hard stone, weighing about 150 ℔s. per foot cube.

From 1st May, 1828, to 31st December, 1831, at Ireland.

,, *g.* $\frac{\text{Bushels quick-lime } 76396}{\text{Bushels coal } 27292}$; or say 1 coal : 2·8 quick-lime, or 1 coal : 2·8 × 1·75 [14] = 4·9 slaked.

At the Ferry Kiln, St. George's, 1830. Hard stone, weighing about 165 ℔s. per foot cube.

,, *g'.* $\frac{\text{Bushels quick-lime } 2153}{\text{Bushels coal } 841}$; or say 1 coal : 2·56 quick-lime, or 1 coal : 2·56 × 2 [14] = 5·12 slaked.

From 1st January, 1832, to 30th November, 1832, at Ireland, same stone as above.

,, *g''.* $\frac{\text{Bushels quick-lime } 17961}{\text{Bushels coal } 6278}$; or say 1 coal : 2·86 quick-lime, or 1 coal : 2·86 × 1·75 [14] = 5 slaked.

Soft stone, weighing about 90 ℔s. per cubic foot.

From January, 1832, to October, 1832, at St. George's.

,, *h.* $\frac{\text{Bushels quick-lime } 9307}{\text{Bushels coal } 2454}$; or say 1 coal : 3·79 quick-lime, or 1 coal : 3·79 × 1·46 [14] = 5·53 slaked.

There were other records at St. George's, but they referred to first attempts at burning: the example given was from a period when greater experience had been acquired.

Hence it should seem, that a given quantity of coal will produce more slaked lime from the soft stone than from the harder sorts; for though it appears at first rather paradoxical that a compact stone should yield less than one of a more porous description, such is not the case; only it takes more time to calcine, and consequently consumes more fuel.

[14] These multipliers are the ratios between quick-lime of different sorts and slaked lime, as given in XIII. *d'*.

XIV. Mortar.

Bulk given *by different proportions* of lime and sand.

" *a.* I give the following experiments, with the results exactly as they occurred, without being at all able to explain their anomalies:

1831. Ireland.

2 bushels of quick-lime were used in each = 3·5 slaked lime.

Slaked lime, bushels	3·5	3·5	3·5	3·5	3·5	3·5	3·5
Sand, bushels	5·	6·	7·	8·	9·	10·	11·
Theoretical bulk	8·5	9·5	10·5	11·5	12·5	13·5	14·5

But slaked lime, when well wetted, shrinks back into bushel for bushel, gaining only the interstices; and sand, thoroughly wetted, lost ($2\frac{1}{4}$ inches in 13 inches of depth) about $\frac{1}{5}$; say then ·8.

With such corrections, obtained by good experiments, we might have expected the reduced bulks to have been:

Lime, bushels .	2·	2·	2·	2·	2·	2·	2·
Sand, bushels .	4·	4·8	5·6	6·4	7·2	8·	8·8
	6·	6·8	7·6	8·4	9·2	10·	10·8
Measurement of the mortar gave however	6·27	6·42	7·	7·62	8·89	[15]	10·8
Differences . . .	+·27	—·38	—·6	—·78	—·31		·0

Here, the only instance in which calculation proved right, was the last, which is nearly in that proportion which the experiments, p. 162, showed, as giving the strongest mortar, 11 : 3·5 instead of 11 : 3·66.

If then any bulk of mortar (say 10·8) be divided by 3, we have $\frac{10\cdot8}{3} = 3\cdot6$, instead of 3·5, the number of bushels of quick-lime; with a trifling excess that insures a sufficiency.

And as 10·8 is somewhat less than 11, the original measure of sand, it shows that the lime and water scarcely fill up the interstices; though there is a great difference between their being so filled with mortar, and their being just occupied by white-wash, as implied by the above-mentioned authority.

As the Islanders use it, 24 bushels of sand and 12 slaked lime gave exactly 24 bushels of mortar, which agrees perfectly with the above, where 7 bushels of sand and $3\frac{1}{2}$ of quick-lime gave 7 bushels of mortar.

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[15] Omitted by accident.

XIV. *b.* Pugging, with a horse at the mill, and convicts preparing. Ireland.

1 Convict at the mouth.
1 Wheeling away.
2 Feeding.
4 Turning over the sand and lime roughly. (When tasked, 15 bushels per day, if the lime be screened; 20, if not.)
1 Ganger.

11 Not including water-carriers, who may or may not be of the party.
1 Sapper, superintending.

In a quarter of an hour 26·86 cubic feet were made, or nearly 4 cubic yards per hour.

,, *c.* Pugging, *by hand. Line soldiers.* St. George's.

1 At the mouth; the sapper in charge.
2 Feeding.
2 Turning the mill and mixing roughly.

In a quarter of an hour, 12 bushels; say 40 bushels per hour, *whilst turning;* but the party must be increased if a continual supply, at this rate, be required, as the same men mix that turn.

XV. Masonry in Escarps.

,, *a.* Bulk of mortar : stone in masonry.

129 cubic yards of masonry, in the 3rd traverse of the Land-front and part of the contiguous Escarp, took 396 bushels of lime (quick), heaped; or 100 cubic yards of such masonry requires 307 bushels of quick-lime, heaped.

As mortar was then used, every $3\frac{1}{4}$ cubic yards of it contained 24 bushels, heaped, of quick-lime; hence 24 bushels lime : $3\frac{3}{4}$ cubic yards mortar : : 396 bushels lime; say 62 cubic yards of mortar, and say the masonry 130 cubic yards, then the proportions of stone and mortar will be:

Mortar . . . . . . $\frac{62}{130} = \frac{31}{65}$

Stone . . . . . . $\frac{68}{130} = \frac{34}{65}$

This however was an extreme case. $\frac{6}{13}$ mortar, $\frac{7}{13}$ stone,[16] will suffice for nearly

[16] As a very fair theoretical deduction from V. *b. b'.* the mortar, as filling up the interstices of the stone, should have been only $\frac{3}{5}$ of $\frac{7}{13} = \frac{4\cdot2}{13}$ instead of $\frac{6}{13}$. But the theorist would overlook

all massive work; with ashlar at face and back, with the heart grouted. In house-walls, about ⅓ will be enough, or mortar : stone : : 1 : 2.

Though the above is not the proportion of lime to masonry that I have used in the following computations, yet it has been stated in the above instance, not only as having actually occurred, but as at all events showing the relation of mortar to stone, whatever proportions of lime and sand may compose that mortar.

XV. *b.* Ashlar masonry in Escarp.

Day-work, sapper. N. E. Ravelin. Retreat Hill, 1831.

1327½ cubic yards masonry, by 554 days of a mason, and 1444 days of a labourer.

The average daily party was, 7 masons, 18 line labourers, of whom 7 were making mortar, and 11 bringing materials.

$\frac{1327 \cdot 5}{554} = 2 \cdot 39$ cubic yards; say 2⅓ cubic yards per mason per day.

Day-work, convict.

Although in one instance day-work gave 2·41 cubic yards per mason and party per day, yet the average of the whole works gave no more than 1⅓ cubic yard.

Task—completed as assigned. See Regulations.

d. Piece-work, sapper or convict masons, with convict labourers.

It must be borne in mind that the quantities executed must always diminish, as the wall rises, from the increased labour in supplying materials.

1st Record.—1830.

Proportion of masons to labourers .	1 : 4·4
Regular work in days	2263½
Time gained in days	1394

$\frac{1394 \times 2}{2263 \cdot 5} = 1 \cdot 23$ cubic yards average daily gain.

2· regular task.

3·23 cubic yards average daily work of 1 mason and 4·4 labourers; or
3·59 do. do. 1 mason and 5 labourers.

2nd Record.—1832.

Proportion of masons to labourers . .	1 : 5
Days' work of 1 mason	390½
Total work, cubic yards	1404

the effects of settlement; and where large estimates might be concerned, what a fatal over-sight!

$\frac{1404 \text{ cubic yards}}{390\cdot5 \text{ days}}$ = 3·59 cubic yards per mason per day, with 5 labourers, as before.

XV. d''. 3rd Record.—1832.

Proportion of masons to labourers	. .	1 : 5
Days' work of 1 mason	. . . .	132·5
Total work, cubic yards	. . . . . .	635

$\frac{635 \text{ cubic yards}}{132\cdot5 \text{ days}}$ = 4·79 cubic yards; not exceeding 18 feet above sea level.

d'''. 4th Record.—1832-1833.

Proportion of masons to labourers	. .	1 : 5
Days' work of 1 mason	. . . .	634
Total work, cubic yards	. . . . . .	2478

$\frac{2478 \text{ cubic yards}}{634 \text{ days}}$ = 3·9 cubic yards per mason per day, with 5 labourers.

,, d''''. 5th Record.—1832-1833. Coping.

Proportion of masons to labourers	. .	1 : 6
Days' work of 1 mason	. . . .	68
Total work, cubic yards	. . . . . .	289½

$\frac{289\cdot5 \text{ cubic yards}}{68 \text{ days}}$ = 4·25 cubic yards per mason per day, with 6 labourers.

XVI. Masonry in retaining and thin walls. Ireland.

Day-work, convict. Dock-yard, retaining wall of Curtain G. H.

Party employed, 6 masons, 13 labourers, 1 free superintendent.

As long as the height did not require a scaffold, 127 cubic yards were executed in 96 days of 1 convict mason and party.

a. $\frac{127}{96}$ = 1·32 cubic yard per day per mason.

When completed to its full height of 19 feet, including the above, 1644 days net, 1 convict mason.

,, a'. $\frac{42490 \text{ cubic feet}}{1644 \text{ days, } 1 \text{ mason}}$ = 25·84 cubic feet per mason per day.

The above time includes scaffolding, materials delivered, and work done in small cross-cut saw ashlar.

,, c. Black.—At the guard-house, cook-house, &c., &c., built for the temporary barracks at Hamilton, in 1831, in the day of 9 hours net, in 1 foot 6-inch walls, where the outside was sawn, trimmed, and pointed; but the inside axe-trimmed and rough-pointed by others. 30 stones, 2 feet × 1 foot × 6 inches, well finished, was as much

as was considered fair by the Island people; and on the whole seemed to be so, taking the circumstances of climate, &c., into account.

Hence, 3 stones per hour, nominal time, per mason and 1 labourer. Materials delivered, and mortar made.

Low as this rate of progress appears, yet, on taking all the delays of fitting, trimming, and pointing, &c., it is as much as can be expected from slave labour; nor will it be found much less than the sapper on piece-work, except that the workmanship of this last is very superior in general to that of Bermuda performances.

XVI. *d.* Piece-work, sapper. Ireland.

With 3 convict labourers, at $1\frac{1}{2}$ yard per day, on about 30 cubic yards of 3-foot retaining wall, knobbled ashlar front, scarcely completed their work.

" *e.* Piece-work, sapper. St. George's.

In building the Military Hospital at St. George's, 2*s.* per cubic yard per mason was allowed, he finding his own line labourer; but materials delivered. They rarely exceeded 30 stones per day, or 30 cubic feet; say 30 cubic feet per mason per day, of 9 hours net. Inside trimming and pointing were required.

N.B. This is about the same bulk that was excavated in soft rock on piece-work. See IV. *b. c. d. e.*

" *f.* Black.—For a short time, towards the close of the work at Hamilton, in 1831, a few of the best did about 2 cubic yards per day, in building the walls of an oven, where no particular workmanship was required.

XVII. Masonry in arches, casemate.

" *a.* Piece-work, sapper and convict. Ireland.

In the casemates of Bastion E, with sufficient convict labour to keep materials well supplied, the sapper mason had 1*s.* per yard for building, and did about $2\frac{1}{3}$ cubic yards per day.

" *a'.* In the archway of the main entrance at Ireland, 1 sapper to 2 convict labourers, materials delivered, built in the ashlar that they had cut, at the same rate as in the preceding.

XVIII. Brick-work in casemate arches.

" *a.* Piece-work, sappers and convicts. 3 bricklayers and 6 labourers, turning casemate arches of the right flank of the Land-front, did $92\frac{1}{2}$ cubic yards in 13 days, net time, materials delivered.

$\frac{92 \cdot 5}{3 \times 13} = 2 \cdot 37$ cubic yards per diem per bricklayer; 10*d.* per cubic yard was allowed. Whilst employed on the larger arches, of 15 feet span and 3 feet thick, they earned

2*s*. 3*d*. per day; but whilst on the 3-foot trimmer-arch, running along the rear, not more than 1*s*. 6*d*. per day.

XVIII. *b*. Convict.—To do such work, however, requires good bricklayers. Steady convict workmen could hardly complete the task of $1\frac{1}{2}$ yard per day, on the casemates of the 3-gun battery; all materials delivered.

„ *c*. $1\frac{1}{4}$ cubic yard, or 500 bricks per day, per bricklayer and labourer, is a fair task in massive work; materials delivered and mortar made.

„ *d*. Equal proportions of sappers and convict labourers, at the 32-foot magazine-road arch, gave 2·2 cubic yards per bricklayer per day; all materials delivered.

XIX. *a*. Roofing with Bermuda Slate. Day-work.

In the roof of the Guard-House at Hamilton, 52 feet × 22 feet = 1144; say $11\frac{1}{2}$ squares; 1700 slates were used, and 70 bushels of mortar.

$\frac{1700}{11\cdot5} = 148$; say 150 slates per square; but allowance must be made for waste.

„ *b*. $\frac{70}{11\cdot5}$ = say 6 bushels of mortar per square; or, as by XIV. *a'*., 6 bushels of sand, and 3 bushels of slaked lime, per square, not including contingencies.

„ *c*. The weight of 1 square of slating will vary from 2000 lbs. to 2800 lbs., according to the thickness of the slabs.

„ *d*. Task, sapper.—1 slater and his labourer to complete 1 square per diem.

„ *e*. Black.—The roof of a store at Ireland, measured 51 feet 8 inches × 20 feet 8 inches = 967·76 superficial feet = 9·67 squares. By the following party it was completed in $6\frac{3}{4}$ hours:

6 masons, fully supplied by
1 labourer, mixing mortar.
2 „ fetching sand.
2 „ handing on slates.
1 boy, passing on mortar.
1 „ bringing water.

Hence $967 \times 9 \div 6\frac{3}{4} \times 6 = 229$ superficial feet per mason per day of 9 hours net; so supplied, say $2\frac{1}{4}$ squares.

In this instance the men exerted themselves to the utmost; so that, as confirmed by the following, 2 squares per mason fully supplied is enough.

Roofing Guard-House and Bakery at Hamilton.

„ *e'*. $11\frac{1}{2}$ squares were laid as a task in 1 day's work, $10\frac{1}{2}$ hours,

by 5 masons, fully supplied by
8 labourers, passing slate and mortar.
2 „ mixing mortar.

Hence $11\frac{1}{2} \times \frac{18}{21} \times \frac{1}{5} = \frac{69}{35} = 2$ squares nearly per mason per day of 9 hours net: the men worked very briskly.

XX. Shingling. From the Dock-yard, Ireland.

	Shingles.	Time of lasting.	Price.	Demanded.	Lap.	Day-work.	Nails per square.
,, *a.*	Cypress	12 years.	£2 per M.	by the M.	6 in.	¾ of 1 square.	8 lbs. 6 oz.
	White Cedar	10 ,,	Do.	Do.	Do.	Do.	Do.
	Boston chips	6	£1 6*s.* do.	ditto, but in bundles.	4 in.	1 square.	6 lbs. 4 oz.
	White Pine	8	£1 10*s.*	Do.			8 ,, 6 ,,

Cypress and Cedar should be 18 inches long, and 4 in breadth. If the pitch of the roof is less than ½ span, more lap must be allowed. The Cypress shingles should be drawn out to a thin edge; the edges shot; and holes bored by a centre-bit, several at once: thus prepared, they lay better and last longer. It takes as long to shoot and shave as to lay. For Boston chips, pitch never less than ⅓ span.

On a roof at Ireland, 27½ feet × 30 feet = 825 feet superficial, it consumed, including ordinary waste, 36 bundles of Boston chips, and 56 lbs. of shingling nails. 4-inch lap.

Theoretically, taking the bundle at 250 chips or 1000 running inches (which is the expected quantity), taking each at 4 inches, and at 4 inches lap, there would have been 29·7 bundles.

b. Hence $\frac{6 \cdot 3}{29 \cdot 7} = \cdot 21$; say 25 per cent. waste, at least.

$\frac{56 \text{ lbs. of nails}}{8 \cdot 25}$ = say 7 lbs. shingling nails per square.

d. 1 square per day, judging by the ease with which this was executed, at ¾ square, is an easy 8 hours' [illegible] for 1 sapper (if a carpenter) and his labourer.

XXI. Cementing.

In cementing the arches mentioned in XVIII. *a.*, they and their drains, bearing an upper surface of 850 superficial feet, took 8½ barrels of cement, containing 6 bushels each, laid on ¾-inch thick; or

6 bushels per square, when ¾-inch thick;
or 8 do. do. 1-inch do.

b. Daily task for 1 plasterer and his labourer (at Ireland) ¾ square.

This work should never be given on piece-work, and requires careful superintendence.

XXII. Coal Tar.

Tar-work,—washes, cements, &c., &c., &c., occasionally used.

1831. Roof of the new Guard-House at Ireland, containing 22 feet × 21½ feet = 473 feet; say 4¾ squares, received 2 coats of this, mixed with pitch and train oil.

„ *a.* Imperial gallons. 18¾ coal tar.
2⅞ pitch.
¾ train oil.

22⅜ gallons composition.

Then

			Imperial gallons.			Dry gallons.	
Coal tar	18·75	÷ 4·75 = 3·94	per square, or at 2 coats	1·97	per square, or per coat	2·01	per square per coat.
Pitch	2·875	÷ 4·75 = ·6		·3		·32	
Train oil	·75	= ·16		·08		·08	
	22·375	4·71		2·35		2·41	

Practically at least
2 dry gallons, coal tar, per square per coat.
⅓ „ pitch, „
1/10 „ train oil, „

Without including any allowance for waste and leakage, on voyage and in store.

Roof of Lime-shed to New Kiln, containing 33¾ squares.

1 coat took 56 dry gallons of coal tar, and about ½ cwt. of pitch; no oil was used, perhaps inadvertently.

This only gives 1⅔ gallons of coal tar, per square per coat.
1⅔ lbs. of pitch, „

The first coat of the preceding example was, however, laid on canvass, which must have absorbed more than wood; but its proportions are certainly the most advisable.

b. Bulk and Weight of Pitch and Tar compared.—1831.

Wooden cask, filled with coal tar, weighed 380 lbs.
Do. empty 110

270 lbs. for about 25¾ imperial gallons,
= 10½ lbs. per gallon.

Iron cask, full of pitch or vegetable tar 352 lbs.
Do. empty 82

270 lbs. for 25 imperial galls. = 10⅘ lbs. per gallon.

So that the above-mentioned ½ cwt. of pitch must have measured about 5 imperial gallons.

XXII. *c.* Whitewash and Cement.

At Hamilton Barracks. Guard-House and roof as before. See XIX.

$\frac{1}{4}$ bushel, cement, per coat, or $11\frac{1}{2}$ squares.
$\frac{1}{6}$,, lime, ,,

Add 1 gallon of molasses for every 8 bushels of cement. It gives a toughness to the coating, and renders the newest roof, after the second coat, impervious to rain; as proved on this very roof, when the wash was hardly dry.

Or $\frac{1}{46}$ bushel, cement, per coat per square.
$\frac{1}{69}$,, lime, ,,

Allow 1 brush for 20 squares, 1 coat.

Two men laid this on in $1\frac{1}{3}$ hour; say $1\frac{1}{2}$ hour!
or, One man ,, $2\frac{2}{3}$,, 3 hours.

Then $\frac{3 \text{ hours}}{11\frac{1}{2} \text{ squares}}$ = say $\frac{1}{4}$ hour per square per coat; except for the first, for which allow double time, so that it may be properly rubbed and worked into the stone.

,, *d.* Lime-ash, per square $\frac{1}{4}$ inch thick.

4 bushels slaked lime, 5 of *smith's* ashes,[16] pounded and sifted, $\frac{3}{4}$ gallon of molasses. The lime and ashes to be first mixed as a mortar, and so let remain for a week at least; add the molasses when again beaten up for use. Take care to wet the surface well to which it is to be applied.

In exposed situations this composition should never be laid until after the rainy season, or until there is a fair chance of its setting. It succeeded perfectly on the roof of the Royal Barracks at St. George's, which, until then, had been one constant source of trouble.

N.B.—Lieut. Symonds, R. E., says that it failed eventually.

4 lime and 1 brick-dust, well worked, and rammed on in one coat 6 inches thick; this was used when coping-stone fell short; the bulk was made up sometimes with small *wetted* rubble.

Puzzuolana.

1 part puzzuolana.
1 ,, quick-lime.
2 ,, clean sharp sand.

The puzzuolana and lime to be ground together into powder, and the sand to be mixed afterwards.

Allow, if possible, 2 or 3 days before it is exposed to water, when used in wharf-walls, so that it may set thoroughly. The more this cement is wrought by beating

[16] Common coal ashes are all but useless; the smith's ashes are generally mixed with a good deal of the oxide of iron, which is so valuable an ingredient in many cements.

and pugging, &c., &c., the better.—S. W. Smith, Resident Civil Engineer to the Admiralty at Bermuda.

XXII. *f.*

Ochre.

1 lb. of ochre.
4 lbs. whitening.
½ lb. glue.
1 brush for 20 squares.

For 20 superficial yards of ordinary plastering per coat; varying these quantities, with the more or less absorbent nature of the surface to which the wash is applied.

Lime ash and red earth, used occasionally for covering the tops of parapets at St. George's.

6 parts lime, wet-screened.
2 ,, smith's ashes.
1 ,, red earth.

To be well pugged.—Lieut. Harness.

,, *g.*

Plastering, rendering, and floating.

Sappers allowed 3*d.* per yard superficial for walls, and 3½*d.* for ceiling, including all coats; materials delivered. It is useless to employ any other than regular plasterers. 8 yards for a full 9 hours' day's work is sufficient, if carefully done.—Ireland.

4 bushels lime slaked per square (full allowance) per coat.
4 lbs. ox-hair ,, ,, ,,

Painting.

Royal Engineer Department Regulations at St. George's.

	Shingling.	Plain Outside.	Inside.	
White lead in oil . . .	6 lbs.	4½ lbs.	3½ lbs.	White, 20 superficial yards 1 coat.
Linseed oil	1 quart.	1½ pint.	⅝ pint.	
Turpentine	,,	,,	⅝ pint.	
Painter	1 day.	1 day.	1 day.	
Labourer	·3	·3	·3	

1 brush for 350 superficial yards.

In black paint, make the white lead ⅖ less, and supply its place with ½ the quantity taken away of black. When the wood is old and dry, it will sometimes require as much as ⅓ more oil than is above allowed; at other times it will be found more than sufficient.

In green the whole quantity is the same; the green (verdigris ground in oil) being ⅘ of that quantity, and the white ⅕.

To every superficial 100 yards allow 10 lbs. whitening and 5 pints linseed oil, for putty in stopping; also 1 lb. red lead and ¼ lb. glue in new work, for charging.

Charging, priming, and 2 coats, are the least that can be allowed for effective work.

Sawyer's work.

One of the first things to be made in a new establishment is a saw-pit; and very much of the expedition with which that much of the works connected with the carpenter's shop proceeds, depends on the convenience and efficiency given to this simple branch, as will be seen by the following.

1 sapper, top-sawyer:
1 convict, pit-sawyer.

From an average of 7 months' work, at 7¾ hours per day.

1 day's work.

105 feet superficial of cut,			of white pine, at	2*s*. per C.
60	do.	do.	pitch pine,	3*s*. 6*d*. per C.
60	do.	do.	birch,	do.
60	do.	do.	beech,	do.
60	do.	do.	elm,	do.
53	do.	do.	Nassau or horse-flesh mahogany,	3*s*. 10*d*. per C.

At an old saw-pit, where they first worked, and which was, from unavoidable circumstances, inconveniently arranged, they could do no more than ⅘ of the above.

Carpenters' work.

Sappers only; 3, in 83 days' work of 1 man, laid 742 superficial feet Nassau mahogany flooring, in the Redoubt of the Land-front Ravelin; joists, &c., complete; receiving the material as sawn only; at £1. 5s. per square.

$\frac{742}{83} = 8{\cdot}94$ feet superficial, or nearly 1 yard per diem per man; 7¾ hour days, July and August, 1830.

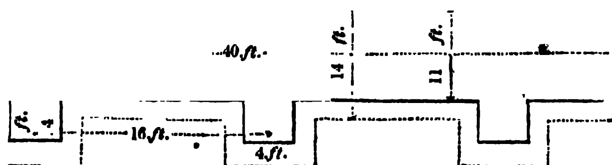
At the sheds in the R. E. department, square, and kiln, 4 sappers, in 97 days' work, completed 4545 superficial feet roofing, in white pine, not planed, but edges shot and battened, at 4*s*. 2*d*. per square.

$\frac{4545}{97} = 57$ feet; say ½ square per man per day of 7¾ hours.

WORK WITH DIVING BELL ON WHARF-WALLS.

Excavating foundation in chalky silt.

Fig. 5. *Plan of wharf-wall foundations, and excavations for the same.*



The foundation, excavated from a stage, exceeded the dimensions of the masonry by about 1 foot 6 inches in breadth, in front and in rear. Average depth, 3 feet 6 inches. In water about 24 feet deep, and tolerably calm. 16 days of the bell, and 2 excavators, at 14 bags per day.

Wall 11 + 3 feet = 14 feet. Then 14 × 40 = 560 feet.
Counterforts $3 \times 7 \times 4 =$ 84

$$\frac{644 \times 7}{16 \times 2} = 141 \text{ cubic feet per bell per day; say 5 cubic yards.}$$

Also $$\frac{2254}{\text{days } 16 \times 14 \text{ bags}} = \frac{2254}{224} = \text{say 10 cubic feet per bag.}$$

Excavation in coral-reef and rock, same line of foundation.

No. of tin cannisters put down.	Weight of powder in each.	No. of days' work.	Quantity excavated. Bags sent up.	Stones sent up.
	lbs.			
1	4	4	40	2
1	4	2½	32	
1	8	4	52	
1	4	2½	29	1
1	4	2½	33	
1	4	1	13	
1	4	2	25	
1	8	3	45	
1	8	3½	43	
1	4	1	8	
1	4	4	53	2
1	4	1	11	
1	8	3	39	3
1	8	4	47	
1	4	8	103	4
1	4	1	5	
3 1	4 2 }	9	126	3
20	90	56	704	15

This Table is a record, by Mr. S. W. Smith, of 2 months' blasting with the bell, at 10 feet low water. Rise of tide at that time, 4 ft.

It gives an admirable representation of the varying difficulties and results of this sort of work; and some idea of the sufficiency of 'Contingencies 10 per cent.' in such wild affairs.

Each bag contained about 9 cwt. of rubbish; or, by the preceding, about 10 cubic feet. The stones, in the last column, were those which were too heavy for the bags; they averaged in weight about 3 bags, or 27 cwt.

Hence $704 + (3 \times 15) = 749$ bags for 56 days' work with 1 bell.

$$\frac{749 \text{ bags} \times 10 \text{ ft.}}{56 \times 27} = \text{very nearly 5 cubic yards per day per bell, as before,}$$

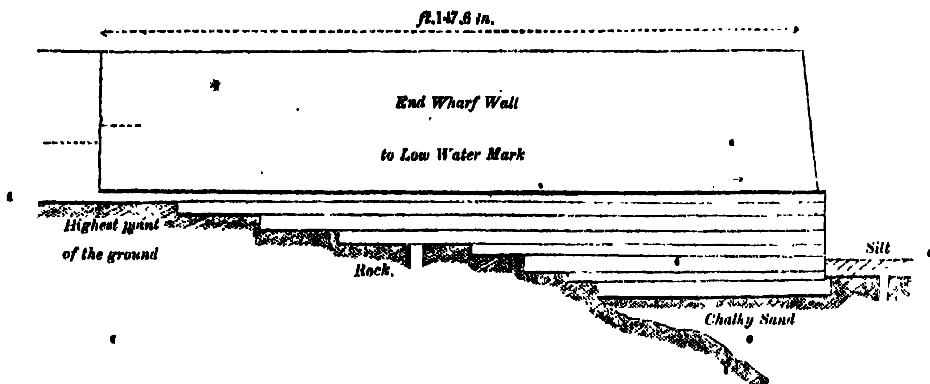
when excavating in chalky silt.

Datum I. *c.*, p. 152, gives 5·6 cubic yards per man per day, as 1 jumper's work in nearly the same sort of rock. But the quantity of powder is far less, the water serving for tamping, and the rock not being quite so sound.

$$\frac{7490 \text{ feet}}{90 \text{ lbs.}} = 83\tfrac{2}{9} \text{ feet per lb., or say 1 lb. for 3 yards cubic.}$$

Excavation and Masonry, on the preceding sorts of foundations, all hollows having been first made good in rubble rammed.

Fig. 6.



The courses varied from 1 foot 6 inches to 2 feet thick. Plan, as given in Fig. 5.

Total content of face.	In lower and erect portion	1018	superficial feet.
	In upper and sloping portion	1609	,,
	Total content	2627	,,
Total content cubic.	In lower and erect portion	11707	cubic feet.
	In upper and sloping portion	16090	,,
		27797	cubic feet, or
		1026	cubic yards.

Excavation and building, including levelling foundations; cut in steps when in rock, and rammed with rubble when hollow in soft soil.

Began 3rd August, 1830, and ended 12th September, 1831; 332 net days.

Then $\frac{27797}{332} = 83 \cdot 72$ cubic feet masonry average, per bell per day.

This, being a mixed example, can give no very definite information beyond the fact that such will repeatedly occur in practice. It was slow work, as will be seen by subsequent examples; but then it was the first of the kind that had been executed at the station, and there is all the extra time and labour in 'pitching the levels' of the courses as they followed the down-hill run of foundation.

Fig. 7. General Section through wharf-wall.

a. Granite coping.

Fig. 8. *Elevation of wharf-wall, showing the portions in which it was built.*

Account of Time and Cement on certain portions of the Wharf-wall, Ireland Island. Same soil, *i.e.* from 1 to 9, chalky silt and sand; from 10 to 13, passing into coral-reef and loose rock.

No. of length in Fig. 8.	Dimensions.				Contents.			Time.				Cement.	Amount of superintendence and labour only.		
	Excavation.		Building.		Excavation.	Building.		Excavation.		Building.					
	L.	B.	L.	D.	bags.	superf.	cubic.	days gross.	days net.	days gross.	days net.	Bushels.	per day.	per foot superficial.	Total.
			ft.	ft.		feet.	feet.							s. d.	
1	See Fig. 6.	Average depth, 3 feet 6 inches.	38	22	..	936	7840$\frac{2}{3}$	..	..	..	83	..	£1. 14s. 6d. per bell per day.	3 5	..
2			39	23	..	897	8437	..	..	..	81	..		3 2$\frac{3}{4}$	..
3			18	..	301	1104	10381	27	24	..	88	..		2 9	..
4			46	..	423	1058	9951$\frac{1}{3}$	33	28	..	90	..		2 11$\frac{1}{4}$	..
5			43	..	..	989	9302$\frac{1}{3}$	..	..	..	83	..		2 10$\frac{3}{4}$	..
6			47	..	..	1081	10167	..	..	129	77	..		2 5$\frac{1}{2}$	..
7			11	..	..	1012	9518$\frac{2}{3}$	..	..	151	79	..		2 8$\frac{1}{4}$	..
8			17	..	279	1081	10167	20	17	87	73	2003		2 4	..
9			51	..	183	1242	11682	15	12	118	88	2805		2 5$\frac{1}{4}$	..
10			62	..	..	1126	13412$\frac{2}{5}$	23	18	127	104	2175		2 6	..
11			78	..	..	1794	16874	..	..	149	124	..		2 4$\frac{1}{2}$	..
12			92	..	..	2116	19902$\frac{2}{3}$	..	..	233	134	..		2 2$\frac{1}{4}$	..
13			81	..	..	1863	17523	..	..	239	123	..		2 3$\frac{1}{4}$	..
			719		1189	16499	155162$\frac{4}{5}$	118	99	1233	1230	6983		30·86*d.*	£2121 15 0

Excavation. By 3, 4, 8, 9. 81 net days gave 1189 bags = 11890 cubic feet; or 146 cubic feet = 5·4 cubic yards per bell per day, as before, nearly.

Building. By 1—13. 1230 net days gave 155162 cubic feet masonry, erect, and sloping; beds level: or 126·15 cubic feet, 4·67 cubic yards, per bell per day of work bearing about 2·5 feet superficial of plain ashlar facing per cubic yard.

By 1—13. 155162 cubic feet cost £2121 15*s.* superintendence and labour only; or 3·28*d.* per cubic foot, 7*s.* 4¾*d.* per cubic yard; say 7*s.* 6*d.*

Cement. By 8, 9, 10. 1306 cubic yards took 6983 bushels, or 5·64 bushels per cubic yard; say 6.

Time.

			Gross	Net
Excavation.	By 3, 4, 8, 9, 10.		118	99
Building.	By 6—13.		1233	802
			1351 :	901 : : 1½ : 1,

including those delays in the arrival of stores, to which works in colonies are liable.

Per Bell per day.

	£.	s.	d
1 Conductor	0	7	6
2 Masons	0	15	0
Ditto, extra time	0	6	0
2 Convict labourers, extra time	0	0	6
22 Convicts	0	5	6
	1	14	6

Not including price of stage, bell, machinery, &c., &c.

Per cubic yard of Wharf-wall.

	£.	s.	d.
Superintendence and labour, as above, in building	0	7	6
Ditto in delivery of materials	0	3	7
Ashlar, plain and bevelled, 2·5 feet superficial, at 5½*d.*	0	1	1¾
Stone, at 3*s.* per cubic yard, allowing for choice and waste	0	3	0
Cement, 6 bushels at 2*s.* 6*d.*	0	15	0
Per cubic yard	£1	10	2¾

What would the amount have been with common free labourers sent from England, at upwards of 6*s.* per day, total charge to a department, beginning of course with excavation!

Example of the different rates in detail, that may be expected in the working of 2 bells, on the same courses, and under the same circumstances, as nearly as may be.

1st Bell.

Course. No.	L.	B.	D.	Cubic content.	Lineal feet per day.	Net days on each course.
	ft.		ft. in.		ft. in.	
1	208	Mean breadth, allowing for counterforts. 10·89 feet.	1 3	2831	7 5	28
2	205		2 0	4465	8 11	23
3	132		1 10	2635	9 5	14
4	136		1 9	2593	8 0	17
5	146		1 6	2385	9 1	16
6, 7	490		1 2, 1 0	5781	8 2	60
				20690		158

2nd Bell.

Course. No.	L.	B.	D.	Cubic content.	Lineal feet per day.	Net days on each course.
	ft.		ft. in.		ft. in.	
1	146	Mean breadth, allowing for counterforts, 10·89 feet.	1 3	1987	4 0	36
2	151		2 0	3289	10 9	11
3	226		1 10	4512	8 4	27
4	225		1 9	4288	8 8	26
5	218		1 6	3561	8 4	26
6, 7	237		1 2, 1 0	2796	7 7	31
				20433		160

$\frac{20690}{158} = 4{\cdot}85$ cubic yards per day. $\frac{20433}{160} = 4{\cdot}73$ cubic yards per day.

As a check on this, compare with the 155162 cubic feet in 1230 days, p. 178.

$\frac{\text{Total building } 41123 \text{ cubic feet}}{\text{Total time, days } 318 \times 27} = 4{\cdot}79$ cubic yards, agreeing very well with the 4·67 of the preceding, which includes more than one half of bevelled ashlar, though in level courses.

Paving executed by Diving Bell; lower part of mast and boat slip.

No. of length.	L.	B.	D.	Feet superficial.	Feet cubic.	Days gross.	Days net.	Bushels Cement.	Remarks.
	feet.	feet.	ft. in.						
1	185	15	1 6	2775	10336	..	97	1135	From the lower edge of the 37½ feet in breadth to the upper, low-water varied from 5 to 2 feet deep.
2	185	22½	1 6	4116		..	98½	1710	
		37½		6891	10336	..	195½	2845	

$\frac{383 \text{ cubic yards}}{195\frac{1}{2} \text{ days}} = 1{\cdot}959$ cubic yards, or 25·16 feet superficial, per day per bell.

$\frac{2845}{383} = 7{\cdot}43$ bushels of cement per cubic yard, or ·41 bushel per foot superficial.

The foundation for this, as in the wharf-wall, was made good, and laid level with rubble rammed: the above was bedded in cement on this. The spaces between, and on each side of the

2 breadths where the stage stood, were put in afterwards by the ship diving bell; the piles having first been cut off flush.

This mast and boat slip was executed in such breadths as the diving bell frame and other circumstances permitted, working across the slope.

Railroad. Ireland, 1830.

Two sappers and 10 prisoners laid 127 yards of railroad, and its bed of rubble (averaging 2 feet in thickness), in 9 days net. They worked well, because they were taken from piece-work until such time as the road should be completed.

Hence $\frac{127}{9}$ = say 14 yards per day, of *such* road, for the whole party; or 7 yards per day per sapper and 5 labourers; materials at hand or delivered.

Tanks. Proportion between tank room and catch: Ireland.

		Feet superficial.
Roof of officers' quarters	57 × 37	= 2109
Do. soldiers' barracks	46 × 22	= 1012
Top of the tank . . .	18 × 14·10 =	267

Total 3388 superficial feet of catch.

Inside dimensions of tank, 10 feet 4 inches × 13 feet 6 inches × 9 feet 3 inches = 1290 cubic feet tank room. Say, however, 1500 cubic feet, as in heavy and continued rains there was waste.

Then $\frac{3388}{1500}$ = say $2\frac{1}{4}$ superficial feet of catch for every cubic foot of tank room.

The above was sufficient for at least 60 persons for 60 days; all water for washing floors, &c., was caught from another roof.

Hence $\frac{1290}{60}$ = say 21 cubic feet per man, at least = 131 imperial gallons, or $2\frac{1}{12}$ gallons per day per man during 60 days, provided the tank be always filled at the commencement.

PART I.

SECTION II.—*Prices founded on the preceding Data, and Tables of Day-work, Task-work, and Piece-work.*

INTRODUCTORY REMARKS.

With reference to the following calculations, &c., I think it due to myself to observe, that the minuteness of detail, especially in the items of superintendence and tools, has not been exhibited as if recommended in practice, but because, after several attempts to avoid it, I found myself reduced to the alternative of either depriving myself of all confidence in the work, from the use of arbitrary allowances on these points, or to place the whole at once on as rigidly mathematical a basis as possible.

And this care was the more necessary, as my object was not so much to give absolute expenses on their own account, as to use them as the means of attaining the professed purposes of the Tables, in showing the *relative* merits in time and money.

1st. Of the different classes of labour, sapper, line, civilian, black and convict, either as compared among themselves on their own system, or on different systems.

2nd. Of the systems of day-work, task-work, and piece-work.

And to this effect, the subject of any square in one Table may be compared with those that cover it in the others: *e. g.*

				1 Day's work.	Expense.
Ashlar VII., by convict	on day-work	.	.	$1\frac{1}{8}$ ft.	7·83*d.* per yard.
Ditto	ditto	task-work	. .	3 ,,	5·37 ,,
Ditto	ditto	piece-work	.	$6\frac{1}{3}$,,	5·09 ,,

The increase in the quantity of work, and the reduction of expense by piece-work, need no comment.

It is to be remarked here, that work and prices in Italics are not to be compared with those in Roman type; as the latter refer to work executed at Ireland in *hard stone;* and the former, to other parts of the colony, chiefly St. George's, where the *soft stone* was used. The circumstances of these two

descriptions are so very different, that they bear but little relation to each other.

3rd. Of similar work in different materials.

In using these Tables the following observations should be borne in mind, with regard to the calculations upon which they are founded:

Superintendence.

Officer of the Line.—

When line labour is employed, allowing a subaltern at 4*s*. to *about* 100 men, his services to the works are charged at $0\frac{1}{2}d$. per man of his own party.

Serjeant of the Works.—

A very necessary person, not only in a military point of view, but as an assistant to the overseer in maintaining general inspection. At Ireland the charge of such a N. C. O. was at least 200 men of all descriptions; hence he has been uniformly allowed for at $\frac{12d.}{200} = \cdot06d.$ per man per day. He had under him 2 or 3 corporals in charge of sappers and their parties.

Sapper.—

At 1*s*. per day.

Convict Mate.—

A civilian, allowed 1*s*. 6*d*. per day from the works when on duty; his charge was about equal to that of the serjeant; hence $\frac{18d.}{200} = \cdot09d.$ per convict per day.

Gangers.—

Well-behaved convicts, generally in charge of about 12 prisoners; they do no other work than looking after their party. Hence $\frac{3d.}{12} = \cdot25d.$ per ganger.

Labour.—The prices of labour are those that would be borne by the Ordnance: as to the actual expense to the nation, I have not attempted it; partly owing to the difficulty, perhaps impossibility, of obtaining accurate information of the *true* cost of a soldier to the Crown (including considerations of food, clothing, quarters, superintendence, medical attendance, transport, &c.; &c.), for comparison with the corresponding items in the convict system. With regard to civilians and slaves, Government having nothing to do with them in these respects, their whole pay is charged, as it would be incurred by the Ordnance; and because that they, like convicts, give no extra services like the more ordinary duties of a soldier. From the best documents I can obtain, with regard to the actual expense of a convict, it seems that 1*s*. 9*d*. per

day is his *total* cost, unless that of the military force necessary for their control be added, which is certainly a national expenditure, though not one of the Ordnance; against which is the consideration, that these men *must* be punished at all events, and that any remuneration obtained from their labour is in fact a bonus.

Tools.—The cost and repair of these are proportioned to the work executed. I consider that for the man who performs the *task*, 1*d.* per working day, or say 25*s.* per annum, taking one trade with another, except wheeling rubbish, is sufficient; and will probably include freight, though not sheers, crabs, &c., or any kind of machinery. In wheeling rubbish, wheeling-plank and wheel-barrows are specially considered. When less than the task has been done, as in day-work, or when more has been done, as on piece-work, the charge has been regulated accordingly. In masonry, where scaffolding is used, 1½*d.* has been substituted for the 1*d.*

Materials.—For the sake of comparison with corresponding work done at other places, each price of materials is independent, and includes the expenses of all processes from the first to the last. Hence the cost of raising stone is included in ashlar; and all this again in masonry. The same holds good with regard to lime. Had I not inserted the expense of raising stone, I could not in the above respect have availed myself of these memoranda beyond the station of Bermuda.

On this account, as military and convict labour are cheap, and the material often expensive, the contrast is not so striking in the different prices, as would have been the case had not the said material entered into the account.

Thus, *with* materials, ashlar,	VII. 𝔄	by convicts on day-work,	is per foot	7·83*d.*
Ditto ditto	VII. ℭ	ditto piece-work	do.	5·09*d.*
		or as 1 : ·65 expense.		

Thus, *without* materials,	VII. 𝔄	by convicts on day-work,	do.	4·33*d.*
Ditto ditto	VII. ℭ	ditto piece-work	do.	1·67*d.*
		or as 1 : ·39 expense.		

The black letter references quote data established by preceding calculations, as distinct, though derived, from those with corresponding Roman numerals in Part I. Section I.

When a square is left blank, it shows that no such work was done by such labour on such system. Data enough are given for calculating the rest with sufficient accuracy in most cases.

No computations are given for the work of convicts at St. George's; they were conducted on the same principles as the rest. I have, however, preserved the rough papers, should any Engineer officer wish to see them. In the piece-work labour and price at that island I have assumed, on the strength of what is said before, that taking one trade with another, ¼ additional work was obtained.

In many of the following instances the labour was so mixed as to do less credit, with regard to economy, to that which gives the denomination, than would have been done had the different classes of labourers worked separately from excavation to building throughout. Thus we have sappers with line labourers, ditto with prisoners; but in no instance is such injustice done, as where expensive civilians are employed on materials raised, prepared, and delivered by convict labourers.

Calculations for the Tables of Prices and Tasks, &c.

EXCAVATION.

	Reference to data.		£.	s.	d.
I. Ditch-work with blasting.		Including turning out stone, preparing for and filling barrows, but not wheeling, or any kind of removal; and supposing dry sand tamping used. No machinery beyond crabs and sheers.			
	I. c.	Taking 5 cubic yards or 1 day's work of 1 jumper.			
A		*Superintendence.*—			
Convict on task-work. Ireland.	p. 182.	Serjeant of works, 5·75 × ·06*d.* = ...	0	0	·34
	,,	N. C. O. in charge of 12 parties @ 1*s.* . .	0	0	1
	,,	Miner in charge of 4 sets or 1 party @ 1*s.* . .	0	0	3
	,,	Convict mate, 5·41 × ·09*d.*	0	0	·48
	,,	Ganger, 1 to 12 prisoners @ 3*d.*	0	0	1·25
		Carried forward	0	0	6·07

Reference to data.		£.	s.	d.
	Brought forward	0	0	6·07
	Labour.—			
	Firing party, sappers, (assisting those in charge) say	0	0	1
	1 Jumper @ 3*d.*	0	0	3
1. *c.*	4 Clearers and fillers @ 3*d.*	0	1	0
p. 183.	Tools and Repairs $5 \times 1d.$	0	0	5
	Materials.—			
I. *b.*	Powder $5 \times 1\frac{3}{4}$ lbs. = 9 lbs., say, @ 6*d.*	0	4	6
I. *a.*	Portfires $\frac{9}{20}$ lb. @ 1*s.* 6*d.*	0	0	8·1
	Tin tubes, say	0	0	2
	5)	0	7	7·17
	Per day, 5 cubic yards per jumper, @ 1*s.* $6\frac{1}{4}d.$ per cubic yard	0	1	6·2

Excavations in which cranes, &c. are used, must be estimated for according to localities: their prices in 1830 were about as follows:—Cranes £300; railroad waggon £18; and tip-carts £10.

V.
ℭ
Convict on task-work.
Ireland.

V. *e.* Same rock and run as the navigators;—180 barrows or cubic feet of solid rock, 60 yards per diem of $7\frac{1}{2}$ hours net. Barrow and plank assumed to last, the former 1 year, and the latter 16 months, from the recklessness of the convicts.

Taking 2000 cubic yards, solid rock, as 1 year's work, or 300 days.

		£.	s.	d.
	Superintendence.—			
	Serjeant of works $(300+25+13)=338 \times \cdot 06d. = 20\cdot 28$	0	1	8·28
	N. C. O. or sapper, 1 to 24; $300 \times \frac{1}{2}d. = 150d.$	0	12	6
	Convict mate, $300+25=325 \times \cdot 09d. = 29\cdot 25$	0	2	5·25
	Ganger, 1 to $12 = 25 \times 3 = 75d.$	0	6	3
	Labour.—			
	300 days of a convict at 3*d.*	3	15	0
V. *j.*	Wheelbarrow and repairs	1	5	0
	Wheeling-plank $\frac{3}{4}$ of a set 2-inch pitch pine, at £10 p. m. bolted at each end	4	13	7
	2000 yards	10	16	5·53
	Per day, $6\frac{2}{3}$ cubic yards solid rock, removed 60 yards @ $1\frac{1}{4}d.$ per cubic yard	0	0	1·29

CUTTING STONE.

	Reference to data.			£.	s.	d.
VII.	p. 158.	Taking 8 yds. sup. or 24 days of 1 man.				
	VII. 𝔄	*Superintendence.*—		0	1	11·56
ℭ		*Labour.*—24 days of 1 man @ 3*d*. . . .		0	6	0
Convict on task-work. Ireland.	I. 𝔄	*Material.*—				
		Splitter, 4 days at 3*d*.		0	1	0
		Stone, 360 cubic feet at ·7*d*. . . .		1	1	0
		Tools, &c. 24*d*. + 4*d*.		0	2	4
			72 feet	1	12	3·56
		Per day, 3 ft. sup. on face @ $5\frac{1}{2}d$. per sup. foot . .		0	0	5·4

BUILDING.

XIII. Burning Lime. — In 1830, the kiln (now assumed to last 10 years) burned 305 days, including Sundays; the remainder of the year having been lost in repairs. It gave during that period 27523 bushels of lime; the total quantity, then, may be

𝔄 — $10 \times 27523 = 275230$ bushels; and this $\div 10 \times 305 = 90$ bushels quick-lime, as the average daily produce of a kiln

Convict labour, Ireland stone. — 18 feet 6 inches deep, 7 feet 6 inches diameter above, and 6 feet diameter below. To supply the 90 bushels, and allow for waste, say 100 bushels of stone as the task

V. *b b′*. & V. *f*. — for 8 men to break up small, when delivered from the quarry; then $10 \times 305 \times 100 \times \frac{89}{2088} \times \frac{3}{5} = 7800$ cubic yards of solid rock, required for the 10 years.

XIII. *g″*. — Coal : quick-lime : : 1 : 2·86. Hence $\frac{275230}{2 \cdot 86} = 96237$ bushels of coal required. Then,—

Price of kiln.

Such as that used at Ireland, with a pit of the above dimensions.

Say 520 cub. yds. of masonry	@ 12*s*.[18]	£312
20 fire brick linings	@ £26.	520
Lime shed. .	. .	120
		952

Carried forward 952 0 0

[18] This is a higher price than for masonry given afterwards, on account of the trouble, &c. of procuring first materials.

Reference to data.		£.	s.	d.
	Brought forward	952	0	0
I. A	*Raising stone.*—			
	7800 cubic yards @ 1*s*. 6½*d*.	601	5	0
	Coal.—			
	96237 bushels @ 2*s*. 6*d*., including cost, freight, delivery, &c., as below	12029	12	6
		13582	17	6

	s.	d.
Cost*	1	4½
Freight	1	0
Landing and waste . .	0	1½
	2	6

* The freight ships only deliver chaldron for chaldron received; what with loading and the voyage, they become *much* increased in bulk, at the expense of actual quantity; hence the loss and waste charged.

	£.	s.	d.
3050 days of 1 sapper burner, day and night, including Sundays, at 2*s*. and 2 convict rakers and fillers at 6*d*.=3*s*.	457	10	0
2610 days of following party, at say 10*s*.	1305	0	0

	s.	d.
Superintendence.—		
Serjeant of works 14 × ·06*d*.	0	0·84
Convict mate 13 × ·09*d*.	0	1·17
1 Ganger to whole party 3*d*.	0	3
Labour.—		
8 convicts breaking stone	2	0
1 delivering from quarry .	0	3
2 carters, 1 sapper, 1 convict	1	3
2 carts and horses . .	5	0
Repairs of carts, tools, &c.	1	0
	9	11·01

15345 7 6

Hence $\frac{£15345\ 7s.\ 6d.}{275230} = 1s.\ 1{\cdot}38d.$; say 1*s*. 1½*d*. per bushel of quick-

XIII. *d'*. lime delivered on the works, or $\frac{1s.\ 1\frac{1}{2}d.}{1{\cdot}75}$ = say 7¾*d*. per bushel of slaked lime also delivered.

	Reference to data.		£.	s.	d.
		Take 1 year's burning, or 330 days.			
		Price of kiln[19] (same content), repairs, and shed; this last much smaller than that at Ireland, as the works were by no means so extensive	5	0	0
𝔅 St. George's. Soft stone. Sapper labour.	V. *b b′.* and V. *f.*	Raising $330 \times 100 \times \frac{89}{2088} \times \frac{5}{5} = 844$ cubic yards of rock at 6¾*d.*, and delivering, say 844 cubic yards in rubbish at 8*d.*	50	2	3
	II. 𝔄 V. 𝔅	Coals $\frac{330 \times 90}{3{\cdot}79} = 7836$ bushels at 2*s.* 6*d.*	979	10	0
	XIII. *h.*	1 sapper, day and night, at 2*s.*, and 1 sapper, by day, at 1*s.*	49	10	0
		1 cart and horse delivering; tools, repairs, &c., &c., at 3*s.* 10*d.*, 300 days	57	10	0
		Superintendence—$3 \times 330 \times {\cdot}06d. = 59{\cdot}4d.$; say 5*s.* .	0	5	0
			£1141	17	3

Hence $\frac{£1141\ 17s.\ 3d.}{330 \times 90} = 9{\cdot}22d.$, say 9¼*d.* per bushel quick-lime delivered

XIII. *d.* on works, or $\frac{9\frac{1}{4}d.}{1{\cdot}46}$ = say 6½*d.* per bushel of slaked lime also delivered.

		£.	s.	d.
XV.	Taking 6 cubic yards or 3 days of 1 mason and party.			
ℭ	*Superintendence.*—			
½ Sapr. ½ Convt. } Masn.	Serjeant of works $\frac{3}{8} + \frac{3}{4} + 3 + 12 + 1\frac{1}{2} + \frac{11}{2} = 23\frac{1}{8} \times {\cdot}06d.$	0	0	1·38
Convict labourer,	N. C. O. 1 to 8 masons, ⅜ of 1*s.*	0	0	4·5
Task-work.	Convict mate $\frac{3}{4} + 3 + 12 + 1\frac{1}{2} + \frac{11}{2} = 22{\cdot}75 \times {\cdot}09d. = 2{\cdot}04d.$	0	0	2·04
Ireland.	Ganger, 1 to 4 masons, ¾ of 3*d.*	0	0	2·25
	Labour.—			
	3 days of 1 mason (½ sapr. ½ convt.) at 7½*d.* .	0	1	10·5
	12 days of 1 labourer at 3*d.*	0	3	0
	1½ days of 1 trimmer at 3*d.*	0	0	4·5
	½ day of a truck party at 2*s.* 9*d.*	0	1	4·5
	Tools and repairs $3 + 12 + 1\frac{1}{2} + \frac{11}{2} = 22d.$	0	1	10
	Carried forward	0	9	3·67

[19] The kilns at St. George's were little more than pits excavated, as required in the very soft rock at Retreat Hill, close to the counterscarp.

	Reference to data.		£.	s.	d.
		Brought forward	0	9	3·67
		Materials.			
	VII. 𝕮	2 × 9 ft. of facing = 18 ft. at 5½*d*. . . .	0	8	3
	IX. 𝕭	2 × 9 ft. of lining = 18 ft. at 2¾*d*. . . .	0	4	1·5
	I. 𝕬	2 × ½ cub. yd. backing = 1 cub. yd. at 1*s*. 6½*d*.	0	1	6·5
	XIV. 𝕭	2 × 1⅖ cub. yd. mortar = 2⅘ cub. yd. at 6*s*. 9½*d*.	0	19	0·2
		6 yds.)	2	2	2·87
		Per day 2 cub. yds. per mason and party at 7*s*. 0½*d*. per yd.	0	7	0·48
	XV. *d*. *d′ d″*. *d‴ d⁗*.	Taking 21 cub. yds., or 6 days of 1 mason and party.			
𝕮		*Superintendence.*—			
½ Sap^r. ½ Con^vt. } Mas^n.		Double the above = 2 × 10·17*d*. . . .	0	1	8·34
Convict labourer, Piece-work. Ireland.		*Labour.*—			
		10½ days of a mason (½ sap^r. ½ conv^t.) at 7½*d*. .	0	6	6·75
	p. 166.	6 days of 4 labourers at 3*d*.	0	6	0
		4½ days of 4 labourers at 1½*d*. . . .	0	2	3
		3 days of 1 trimmer	0	0	9
		1 day of a truck party at 2*s*. 9*d*. . . .	0	2	9
		Tools and repairs, &c. 2 × as above, 22*d*. × $\frac{21}{12}$ task = 77*d*.	0	6	5
		Materials.—			
	VII. 𝕮	7 × 9 ft. facing = 63 ft. at 5¼*d*. . . .	1	7	6·75
	IX. 𝕬	7 × 9 ft. lining = 63 ft. at 2¾*d*. . . .	0	14	5·25
	I. 𝕬	7 × ½ cub. yd. backing = 3½ cub. yds. at 1*s*. 6½*d*.	0	5	4·75
	XIV. 𝕬	7 × 1⅖ cub. yds. mortar = 9⅘ cub. yds. at 6*s*. 9½*d*.	3	6	6·7
		21 yards)	7	0	4·54
		Per day 3½ cub. yds. per mason and party at 6*s*. 8¼*d*. per yd.	0	6	8·21

Tabular Exhibition in Time and Money of the comparative Values of Convict and other Labour, on the system of

DAY-WORK.

	Description of work.	*No.*	*Sapper.*	*Line.*	*Civilian.*	*Black.*	*Convict at Ireland Island.*	*Convict at St. George's.*
Excavation.	Ditch-work with blasting.	I.						
	Ditch-work without blasting.	II.						
	Gallery with blasting.	III.					9 cubic feet per man, 3*s*. $1\frac{3}{4}$*d*. per cubic yard.	
	Gallery and shafts without blasting.	IV.						
	Wheeling rubbish.	V.						
	Scarping.	VI.					$3\frac{3}{4}$ superficial feet per man, 1*s*. per superficial yard.	
Stone-cutting.	Ashlar, wrought by chisel and point.	VII.					$1\frac{1}{8}$ superficial ft. on face per man, 8*d*. per superf. ft.	
	Do. by plate saws.	VIII.					$\frac{1}{3}$ superf. foot of cut per man, 1*s*. $5\frac{1}{4}$*d*. per foot superf. of 3-in. slab.	
	Do. by cross-cut saws.	IX.					$2\frac{1}{3}$ superf. foot on face per man, 4*d*. per superf. foot.	
	Do. by knobbled work.	X.						
	Do. in arches and embrasures.	XI.						

Building in general.	Mortar.	XIV.		
	Masonry in thick and escarp walls.	XV.	*2⅓ cubic yards per mason, 6s. 6½d. per cubic yard.*	1⅓ cubic yard per mason, 8s. 7⅓d. per yard cubic.
	Do. in thin and retaining walls.	XVI.		25½ cubic feet per mason, 11s. 8½d. per yard cubic.
	Do. in arches.	XVII.		
	Brickwork in arches.	XVIII.		
	Roofing with Bermuda slate.	XIX.		
	Roofing with shingles.	XX.		
	Cementing.	XXI.		

No comparison is to be made between the labour in soft stone, given in Italics, and that in hard stone, printed in Roman type.

For explanations, see pp. 181 and 182.

Tabular Exhibition in Time and Money of the comparative Values of Convict and other Labour, on the system of

TASK-WORK.

	Description of work.	*No.*	*Sapper.*	*Line.*	*Civilian.*	*Black.*	*Convict at Ireland Island.*	*Convict at St. George's.*
Excavation.	Ditch-work with blasting.	I.					5 cubic yards per jumper, 1*s.* 6½*d.* per cubic yard.	
	Ditch-work without blasting.	II.	2 *cubic yards per man, 7d. per cubic yard.*	2 *cubic yards per man, 6¼d. per cubic yard.*				3 *cubic yards per man, 1¾d. per cubic yard.*
	Gallery with blasting.	III.						
	Gallery and shafts without blasting.	IV.						
	Wheeling rubbish.	V.	1⅓ *cubic yd. solid rock removed 60 yds. per man, 8¾d. per cubic yard.*	1⅔ *cubic yd. solid rock removed 60 yards per man, 8d. per cubic yard.*	20 cub. yds. solid rock removed 60 yards per man, 5¼*d.* per cub. yd.		6⅔ cub. yds. solid rock removed 60 yards per man, 1½*d.* per cub. yd.	8⅓ *cubic yds. solid rock removed 60 yards per man, 1d. per cubic yard.*
	Scarping.	VI.					6 superficial feet per man, 8½*d.* per superficial yard.	
Cutting.	Ashlar, wrought by chisel and point.	VII.			5 ft. superf. on face per man, 1*s.* 10*d.* per superf. foot.		3 feet superf. on face per man, 5½*d.* per superf. foot.	
	Do. by plate saws.	VIII.					1¼ ft. sup. of cut, per man, 8*d.* per ft. sup. 3-in. slab.	
	Do. by cross-cut saws.	IX.	9 *cubic feet per man, 1¾d. per ft. cubic.*	4 *cubic feet per man, 3¼d. per ft. cubic.*			10 ft. sup. on face per man, 2¾*d.* per foot superficial.	14 *feet cubic per man, 0½d. per ft. cubic.*
	Do. by knobbled work.	X.					8 ft. sup. on face [illegible]	

	Raising Bermuda slate.	XII.	*17 slates per man, 7s. 0¾d. per C. of roof.*	*30 coarse slates per man, 8s. 6d. per C. of roof.*		*20 slates per man, 1s. 10½d. per C. of roof.*
Building in general.	Lime.	XIII.	*6½d. per bushel of slaked lime.*		7¾d. per bushel of slaked lime.	
	Mortar.	XIV.	*6s. 8d. per cu. yd.*		6s. 9½d. per cu. yd.	
	Masonry in thick and escarp walls.	XV.			2 cubic yards per mason, 7s. 0½d. per cubic yard.	*2½ cubic yards per mason, 4s. 4¾d. per cubic yard.*
	Do. in thin and retaining walls.	XVI.		*1 cubic yard per mason, 18s. 4¼d. per cubic yard.*		
	Do. in arches.	XVII.				*1¼ cubic yard per mason, 5s. 0½d. per cubic yard.*
	Brick-work in arches.	XVIII.				
	Roofing with Bermuda slate.	XIX.	*1 C. per slater.* *Slating* 0 12 8½ *Framing* 2 18 9 £3 11 5½ *per C. of roof.*	*1¼ C. per slater. Slating 34s. 9¼d. per C. of roof.*		*1 C. per slater. Slating 4s. 11¾d. per C. of roof.*
	Roofing with shingles.	XX.	1 C. per shingʳ. Shingˢ 5 17 11½ Framˢ 1 18 0 £7 15 11½ per C. of roof.			
	Cementing.	XXI.	¾ C. for plasterer, 23*s.* 0¼*d.* per C.		¾ C. per plasterer, 21*s.* 1¼*d.* per C.	

No comparison is to be made between the labour in soft stone, given in Italics, and that in hard stone, printed in Roman type.
For explanations, see pp. 181 and 182.

Tabular Exhibition in Time and Money of the comparative Values of Convict and other Labour on the system of

PIECE-WORK.[20]

	Description of work.	*No.*	*Sapper.*	*Line.*	*Civilian.*	*Black.*	*Convict at Ireland Island.*	*Convict at St. George's.*
Excavation.	Ditch-work with blasting.	I.						
	Ditch-work without blasting.	II.	3 *cubic yards per miner*, $6\frac{3}{4}$*d. per cubic yard.*					$3\frac{3}{4}$ *cubic yards per miner*, $1\frac{1}{2}$*d. per cubic yard.*
	Gallery with blasting.	III.						
	Gallery and shafts without blasting.	IV.	*Gallery.* 1 *cu. yd. per miner*, 2*s. per cubic yard.* *Shafts.* 15 *cu. ft. per miner*, 3*s.* 11*d. per cu. yd.*					
	Wheeling rubbish.	V.	$2\frac{1}{2}$ *cubic yds. solid rock, removed* 60 *yards*, $8\frac{1}{2}$*d. per cubic yard.*	$2\frac{1}{2}$ *cubic yds. solid rock, removed* 60 *yards*, $7\frac{3}{4}$*d. per cubic yard.*				$10\frac{1}{4}$ *cub. yds. solid rock, removed* 60 *yards*, 1*d. per cubic yard.*
	Scarping.	VI.					19 ft. superf. per man, $7\frac{1}{2}$*d.* per superficial yard.	
...ting.	Ashlar, wrought by chisel and point.	VII.	$8\frac{1}{2}$ feet superficial on face per man, 7*d.* per ft. superf.				$6\frac{1}{3}$ feet superf. on face per man, $5\frac{1}{4}$*d.* per ft. superf.	
	Do. by plate saws.	VIII.					$3\frac{3}{4}$ feet superf. of cut per man, $7\frac{1}{2}$*d.* per foot superf. of 3-inch slab.	
	Do. by cross-cut	IX.	$13\frac{1}{2}$ *cubic feet per*	$8\frac{1}{2}$ *cubic feet per*			[illegible]	[illegible]

			per foot super			
	Do. in arches and embrasures.	XI.	8 ft. cub. per man, $5\frac{3}{4}$*d.* per ft. cub.			
	Raising Bermuda slate.	XII.				*25 slates per man, 1s. $4\frac{1}{2}$d. per C. of roof.*
Building in general.	Lime.	XIII.		*Contract price 1s. 6d. per bushel, slaked & delivered.*		
	Mortar.	XIV.				
	Masonry in thick and escarp walls.	XV.			$3\frac{1}{2}$ cubic yards per mason, 6*s.* $8\frac{1}{4}$*d.* per yard cubic.	*$3\frac{1}{8}$ cubic yards per mason, 4s. $4\frac{1}{2}$d. per cubic yard.*
	Do. in thin and retaining walls.	XVI.	*$1\frac{1}{9}$ cubic yard per mason, 7s. $11\frac{1}{2}$d. per cubic yard.*		$1\frac{1}{2}$ cubic yard per mason, 6*s.* $7\frac{1}{2}$*d.* per yard cubic.	
	Do. in arches.	XVII.			$2\frac{1}{3}$ cubic yards per mason, 13*s.* 11*d.* per yard cubic.	*$1\frac{9}{16}$ cubic yard per mason, 5s. per cubic yard.*
	Brick-work in arches.	XVIII.			$1\frac{1}{2}$ cubic yard per bricklayer, 44*s.* $3\frac{1}{4}$*d.* per cu. yd.	
	Roofing with Bermuda slate.	XIX.				*$1\frac{1}{4}$ C. per slater. Slating 4s. $11\frac{1}{2}$d. per C. of roof.*
	Roofing with shingles.	XX.				
	Cementing.	XXI.				

No comparison is to be made between the labour in soft stone, given in Italics, and that in hard stone, printed in Roman type.

For explanations, see pp. 181 and 182.

[20] It must be remembered that the values of work given in this Table cannot be expected at the beginning of any work; some experience will be necessary for all parties.

PAINTING.

Prices used in Estimates at Algoa Bay, 1836.

No. 1.—Stopping, knotting, and priming, per square.

Task, 150 feet per day.

				s.	d.
Data.[21]					
Labour $\frac{100 \text{ feet}}{150}$ { 1 painter at 6*s.*, ⅓ labourer 3*s.* }				4	8
			Loss on labour $\frac{1}{10}$	0	5½
Material, No. 1.	Red lead, per square,	2 oz.	7*d.* per lb.	0	1
2.	Glue, ,,	3 oz.	1*s.* ,,	0	2¼
3.	Whitening,	18 oz.	3*d.* ,,	0	3½
4.	Sand paper,	1 sheet,	1*d.* each	0	1
5.	Pumice stone,	4 oz.	1*s.* per lb.	0	3
6.	White lead,	2¾ lbs.	7*d.* ,,	1	7¼
7.	Black paint,	5 oz.	10*d.* ,,	0	3¼
8.	Raw linseed oil,	1 pint,	6*s.* per gal.	0	9
9.	Boiled ditto,	⅝ ,,	6*s.* 6*d.* per gal.	0	6
10.	Litharge,	3 oz.	1*s.* 3*d.* per lb.	0	3
11.	Sugar of lead			0	0
12.	Turpentine			0	0
			Loss on materials	0	5½
Tools.	Brushes, cans, &c.			0	3
			Per square	10	1¼

No. 2.—Outside, lead colour, twice; per square.

Task, 180 feet per day, once.

				s.	d.
Labour $\frac{\text{twice} \times 100}{180}$ { 1 painter at 6*s.*, ⅓ labourer 3*s.* }				7	9½
			Loss on labour $\frac{1}{10}$	0	9½
Material, No. 4.	(as above)	1¾ sheet		0	1¾
5.	,,	6 oz.		0	4½
6.	,,	5½ lbs.		3	2½
7.	,,	¾ lb.		0	7½
8.	,,	1 quart		1	6
9.	,,	1⅛ pint		0	11¾
10.	,,	6 oz.		0	5¾
			Loss on materials	0	9¼
Tools, as above				0	6
			Per square, twice	17	2

[21] The data thus referenced accompanied the Analysis of Prices appended to the Estimates. All

No. 3.—Inside, lead, twice; ditto as before.

Data.				*s.*	*d.*
Labour.	Ditto No. 2.			8	7
Material, No. 4.	(as before)	1¾ sheet		0	1¾
5.	,,	6 oz.		0	4½
6.	,,	5½ lbs.		3	2½
7.	,,	¾ lb.		0	7½
8.	,,	1 pint		0	9
10.	,,	3 oz.		0	3
12.	,,	1 pint		0	7½
			Loss on materials	0	8
Tools, as before				0	6
			Per square, twice	15	8¾

No. 4.—Inside, white, twice; ditto as before.

Labour.	Ditto No. 2.			8	7
Material, No. 4.	(as before)	1¾ sheet		0	1¾
5.	,,	6 oz.		0	4½
6.	,,	5½ lbs.		3	2½
8.	,,	1 pint		0	9
11.	,,	1½ oz.		0	1
12.	,,	1 pint		0	7½
			Loss on materials	0	7
Tools, as before				0	6
				14	10¼

No. 5.—Outside, white, twice; ditto as before.

Labour.	Ditto No. 2.			8	7
Material, No. 4.	(as before)	1¾ sheet		0	1¾
5.	,,	6 oz.		0	4½
6.	,,	5½ lbs.		3	2½
8.	,,	1 quart		1	6
9.	,,	1⅛ pint		0	11¾
10.	,,	6 oz.		0	5¾
			Loss on materials	0	8¾
Tools, as before				0	6
				16	6

the above prices were just after the Kafir war, and when works were ordered by the Governor on Treasury warrants; there not having been time to refer to the authorities at home.

XII.—*Notices on the New Victualling Establishment at Devonport. By Lieut.* NELSON, *in the absence of Major* WORTHAM, *and accompanying the Drawings of the Cast-Iron Roofs by the latter.*

DURING the war provisions and other pursers' stores were issued to the shipping at Devonport and Plymouth in the inconvenient way that might have been expected where establishments, like the purposes to which they relate, were not comprehensively provided for in the first instance, either from limited views and finances on the part of the projectors, or from such an enormous extension of all original designs as has occurred in the course of the present century in so many departments, that even a perfectly prophetic foresight would have been apt to have led into useless expense, by the construction of gigantic edifices which would not have been fully wanted until the closing portion of the period.

Long, however, before 1816, the annoyances of an accidental provision were felt by those who had to draw their supplies from different corners of the Sound and Hamoaze: at one time, the Brewery was at Millbrook; the Slaughter-house at Stonehouse; the bread was baked at Plymouth; water, when the weather permitted, was to be obtained from Bovisand; and other items in the purser's charge from the dock-yard.

It was therefore determined to give up this system of detached buildings; and the present noble establishment at East Cremill more than supplies their place. With reference to the accompanying sketch, the Royal William Yard, as it now stands, consists of Plate XV.

A. The Quadrangular (or Melville) Storehouses and Offices.
B. Cooperage.
C. Long Storehouse.
D. Flour-mill and Bakery.

E. Brewery.

F. Slaughter-house. { a. Abbattoir, &c. b. Sheds for cattle. c. Court-yard. d. Gate. }

G. Wharf.

H. Basin; a. Iron Turning-bridge.

I. Tunnel, leading to Firestone Bay.

J. Sea-wall.

K. Reservoir.

L. Cellars.

M. Gateway and Police Establishment.

N. Engine-house.

O. Officers' houses.

P. Gardens.

The Flour-mill and Brewery are both unfinished, as far as much of the machinery is concerned. The former mounts 12 hoppers, supplying the Biscuit-bakery with meal, and the shipping with flour.

The 12 ovens can produce about 24,000 lbs. of bread as an ordinary day's work. The Brewery is intended only to meet the demands from the Harbour and Sound, or at most from the Channel; beer not being a long-voyage store.

The Storehouses in general are computed to hold pursers' stores of every description for 40,000 men for 4 months.

The Slaughter-house is arranged to provision the like number, as it will hang 70 ox-carcasses; the Devonshire cattle of the contract quality giving about from $4\frac{1}{2}$ to $5\frac{1}{2}$ cwt. net, at a year's average.

The Wharf is properly equipped with cranes, &c.; and in it also are the pipes from the Reservoir on the hill above, to fill the tank-vessels by which the ships are supplied. The water is brought by the Town conduits from Dartmoor.

The Basin, as well as the Tunnel leading to Firestone Bay, allows choice of side as to shelter from the prevailing winds. The Sea-wall J is built in rubble on a curved section, like that of the lower part of the Eddystone.

When I left Devonport in 1828, the site was an ordinary hill; on my return in 1833, it was to a very great extent effective, and though it is by no means completed at the present moment, still it is worthy of the nation; and to Messrs. Rennie, the architects, an honourable testimony of talent, both in artist-like conception and workman-like detail of execution. The mode in

which the cold-coloured local material,—a grey limestone,—has been warmed by the use of the colder Penryn granite as a relief, is very striking, both from its own success, as well as from the chilly unpleasant contrast afforded by the appearance of almost every neighbouring public building, in which such arrangements have been almost entirely neglected.

Plates XVI XVII The beautiful iron-work forming the subject of the accompanying engravings is the performance of Mr. G. Rennie.

MEMORANDUM.

There is only one intermediate rafter between each pair of principals.

The tie-bars shown in the elevations are connected with each other by 2 tie-bolts, 1 inch in diameter, running in the length-way of the roof of the quadrangular storehouse.

Horizontal bars cross the rafters, to which the slating boards, placed vertically on the roof, are fastened by iron staples clenched on the outside.

Rough Sketch of the
NAVAL
VICTUALLING ESTABLISHMENT
at
DEVONPORT.

PLYMOUTH SOUND

FIRESTONE BAY

Old Preventive Service Tower

Redoubt

Devil's Point Practice Battery

STONEHOUSE POOL

HAMOAZE

A

B

K

P

L

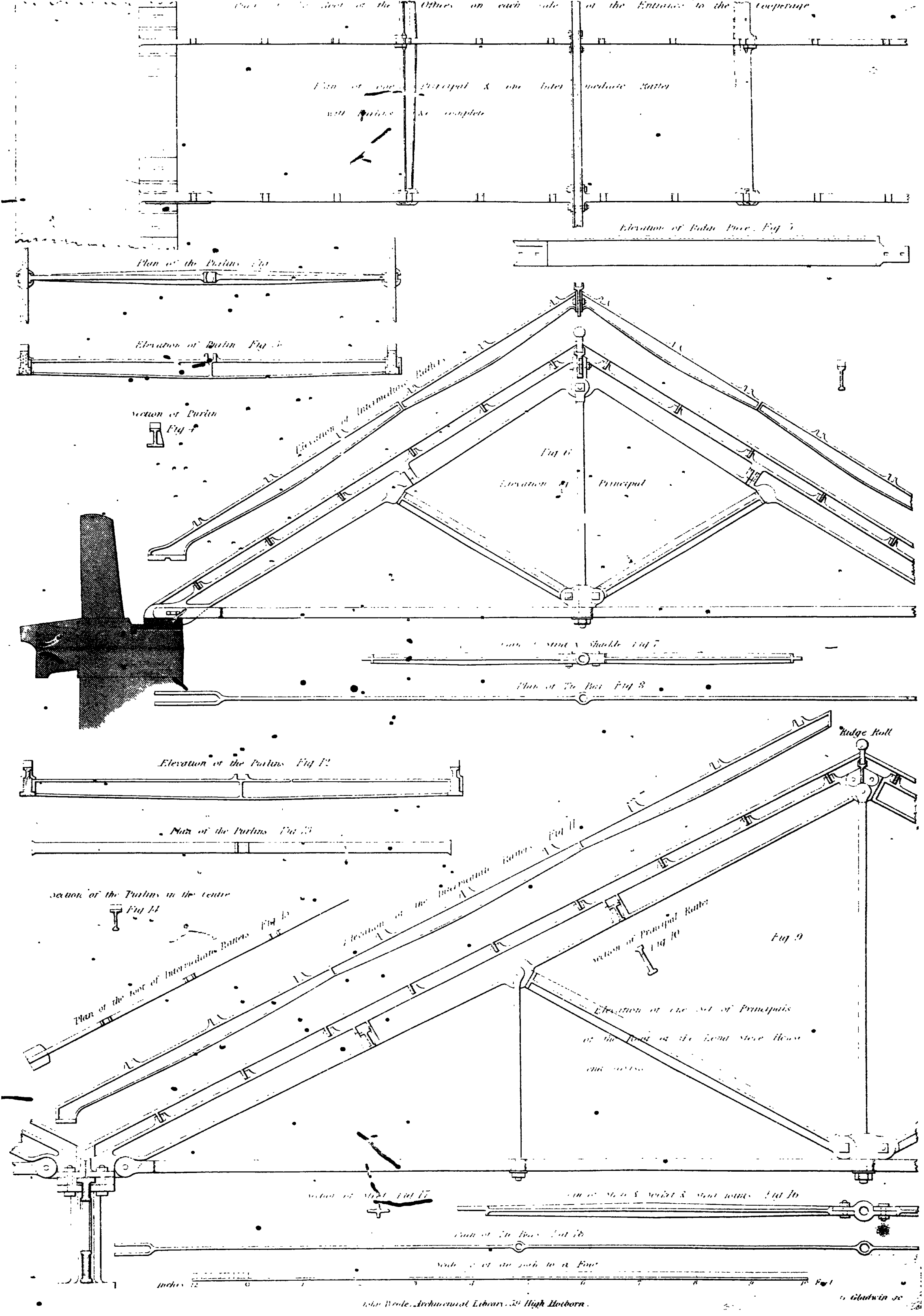
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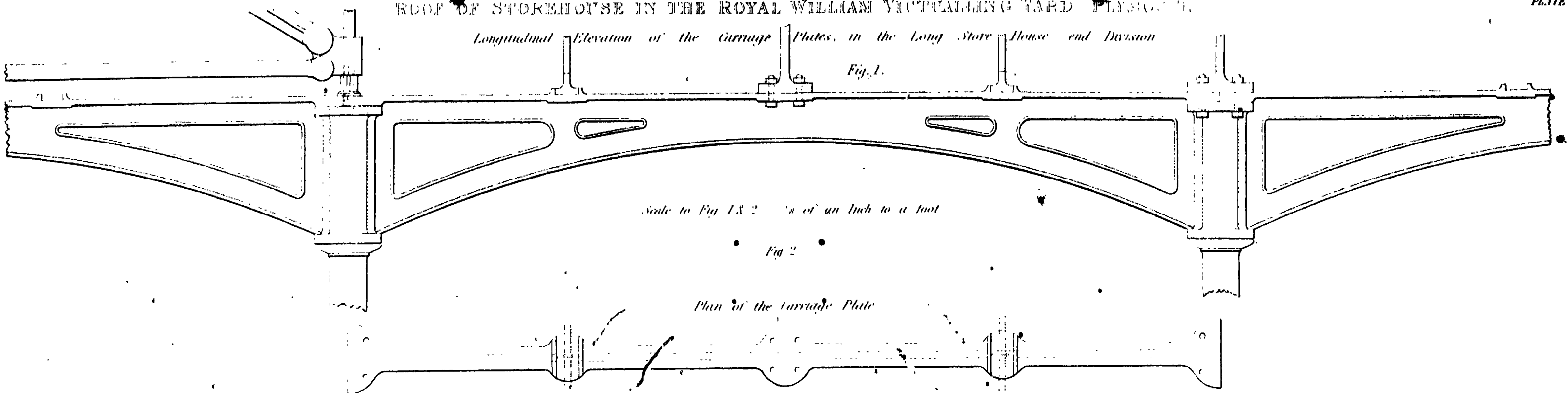
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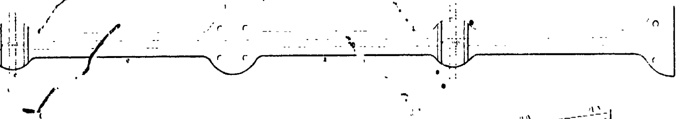
100 Yards

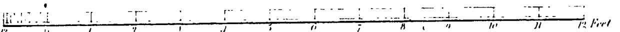
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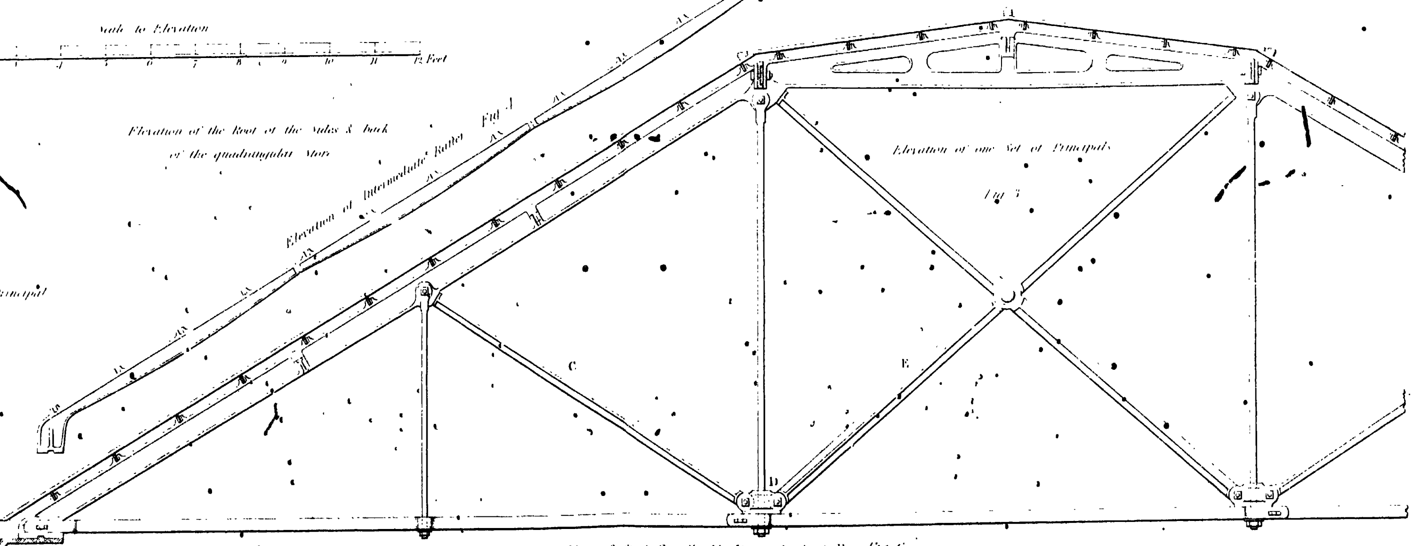

of the Offices on each side of the Entrance to the Cooperage
Plan of one Principal & one Intermediate Rafter
with Purlins &c complete
Elevation of Ridge Piece, Fig 5
Plan of the Purlins
Elevation of Purlin Fig 3
Section of Purlin
Fig 4
Elevation of Intermediate Rafter
Fig 6
Elevation of Principal
Strut & Shackle Fig 7
Plan of Tie Bar Fig 8
Ridge Roll
Elevation of the Purlins Fig 12
Plan of the Purlins Fig 13
Section of the Purlins in the centre
Fig 14
Plan of the foot of Intermediate Rafters Fig 15
Elevation of the Intermediate Rafters Fig 11
Section of Principal Rafter
Fig 10
Fig 9
Elevation of one set of Principals
of the Roof of the Lead Store House
Fig 17
Fig 16
Inches 12 0 1 2 3 4 5 6 7 8 9 10 Feet
John Weale, Architectural Library, 59 High Holborn.
G. Gladwin sc

ROOF OF STOREHOUSE IN THE ROYAL WILLIAM VICTUALLING YARD PLYMOUTH









Memorandum of Dimensions of Iron-work of Roofs at the Royal William Victualling Establishment, Plymouth, constructed by Sir John Rennie.

Span.	Principal Rafters, (cast.)	Intermediate Rafters, (cast.)	Tie-bars, (wrought.)	King-bolts, (wrought.)	Queen-bolts, (wrought.)	Struts, (cast.)	Purlins, (cast.)
44. Sides and back of the quadrangular storehouse.	*width.* *thickness.* *t.* 5¾ } *t. m. b.* *m.* 6½ } × 2 ¾ 1¾ *b.* 5¾ }	*t.* 3 4¼ 2½ 2½ 4¼ *b.* 3 } *t. m. b.* × 1½ ⅝ 1¼	*width. thick^s.* 3 × ¾		*length. diam.* 8·10 × 1⅝ 5·0 × 1⅛	*t. m. b.* *t.* 3¾ × ¾ 2 ⅞ ¾ 3 ⅞ *m.* 4½ × ¾ 2 ⅞ ¾ 3 ⅞ *b.* 3¾ × ¾ 2 ⅞ *t.* 3½ × ¾ 2 ⅞ *m.* 4 × ¾ 3 ⅞ *b.* 3½ × ¾ 2 ⅞	*t. m. b.* *e.* 4 × 1¼ ⅝ 1¼ *m.* 5 × 2½ 3 *e.* 4 × 1¼ ⅝ 1¼
34. Long storehouse, centre division.	*t.* 5½ } *t. m. b.* *m.* 6¾ } × 1¾ ¾ 1¾ *b.* 5½ }	*t.* 3 3½ 2½ 2½ 3½ *b.* 3 } *t. m. b.* × 1½ ⅝ 1¼	3 × 9/16	*length. diam.* 7·3 × 1½	3·11½ × 1¼	*t. m. b.* *t.* 3¼ × ¾ 2¼ ¾ *m.* 4¼ × ¾ 3½ ¾ *b.* 3¼ × ¾ 2¼ ¾	*t. m. b.* *e.* 3½ } *m.* 4½ } 2½ ⅝ 1¼ *e.* 3½ } 6·9 long.
26·10. Long storehouse, end divisions.	*t.* 5¼ } *t. m. b.* *m.* 6 } × 1¾ 11/16 1¾ *b.* 5¼ }	*t.* 3 3½ 2½ 2½ 3½ *b.* 3 } *t. m. b.* × 1½ ⅝ 1¼	2 13/16 × ½	7·3 × 1½	3·11 × 1⅛	*t. m. b.* *t.* 3¼ × ¾ 1¾ ¾ *m.* 4 × ¾ 2 ¾ *b.* 3¼ × ¾ 1¾ ¾	*t. m. b.* *e.* 3½ } *m.* 4½ } 2½ ⅝ 1¼ *e.* 3½ } 6·9 long.
20. Coopers' shops.	*t.* 5⅛ } *t. m. b.* *m.* 5¾ } × 1¾ 11/16 1½ *b.* 5⅛ }	*t.* 2½ 3½ 2⅜ 2⅜ 3½ *b.* 2½ } *t. m. b.* × 1⅜ 9/16	2¾ × 11/16	4·7¾ × 1½		*t. m. b.* *t.* 3¼ × ⅝ 1¾ ¾ *m.* 3¾ × ⅝ 2¾ ¾ *b.* 3¼ × ⅝ 2 ¾	*t. m. b.* *e.* 3½ × 1⅛ ⅝ 1⅛ *m.* 4¾ × 2½ 3 *e.* 3¼ × 1⅛ ⅝ 1⅛
14·3. Offices each side of entrance to cooperage.	*t.* 4½ } *t. m. b.* *m.* 5¼ } × 1⅝ ⅝ 1½ *b.* 4½ }	*t.* 2¼ 3¼ 2⅛ 2⅛ 3¼ *b.* 2¼ } *t. m. b.* × 1¼	2½ × ⅝	4·4½ × 1¼		*t. m. b.* *t.* 3 × 1¾ *m.* 3½ × 2¼ *b.* 2¾ × 2	*t. m. b.* *e.* 3⅛ × 1 ½ 1 *m.* 4¼ × 2½ 3 *e.* 3⅛ × 1 ½ 1 6·6 long.

References. *t.* top-end. *m.* middle. *b.* bottom-end. (in width of rafters and struts.) *t.* top-edge. *m.* middle. *b.* bottom-edge. (in thickness of rafters and struts.) *e.* end. *m.* middle. *e.* end. (in width of purlins.)

XIII.—*Safety-box for connecting a Locomotive Engine and Tender to the Train.* *By* Samuel B. Howlett, Esq. *Chief Draughtsman, Ordnance.*

In a recent accident on a railway, by which the two men upon the engine were killed, and two passengers much injured, it appears that through some unknown cause, the engine got off the rails, and ran obliquely for fifty or sixty yards, when it fell against the bank, dragging the whole train upon itself in one frightful crash. This happened in a cutting; but, if it had happened upon an embankment, the engine would have gone down the slope, and the train would have followed, unless the connecting chain had broken.

Instead, then, of attaching the engine to the train by a fixed chain, as at present, I submit whether it would not be better to form the connexion between the tender and the first carriage by a chain and bar, the bar being inserted into what I have called a safety-box, so contrived that when the engine with its tender shall happen to depart from the rails, they shall instantly be detached from the train.

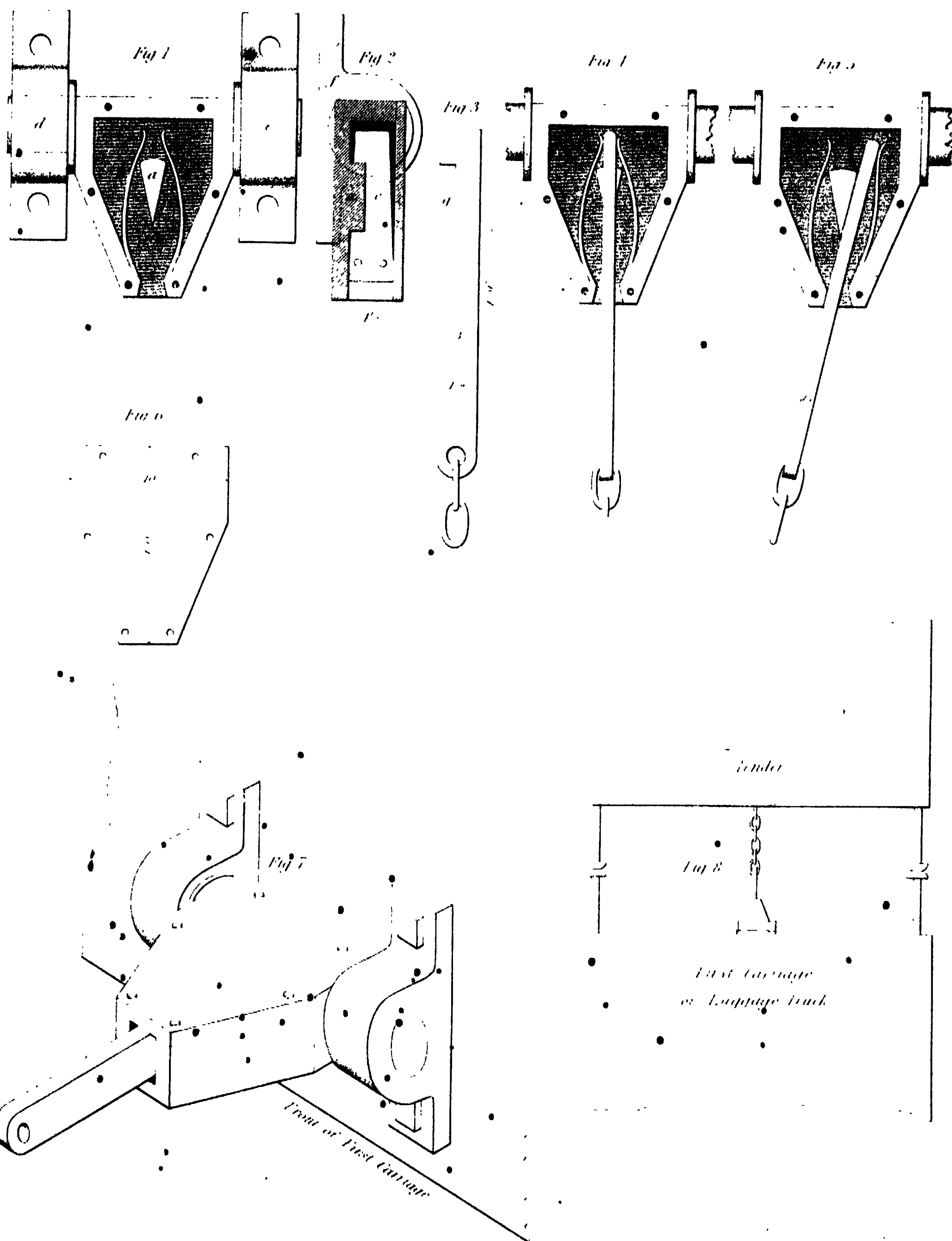
Plate XVIII. Figure 1. A cast-iron box, having a boss *a* cast with it, to the sides of which box the springs *b* and *c* are attached. On the outside of the box are trunnions, or ears, *d*, *e*, working in sockets.

Figure 2. A longitudinal section through the middle of figure 1, showing the boss *a*, the spring *c* behind the boss, the socket *f*, and also the cover to the box.

Figure 3. A side view of the wrought-iron bar, having the part *g* notched out sufficiently to pass freely over the boss at the bottom of the box. To the end of this bar the usual chain may be attached.

Figure 4. The box with the bar. Now, it is obvious that no direct pull could withdraw the bar, because the notch rests over the boss, and the bar, being held by the springs, cannot shift its position laterally without a greater

SAFETY BOX FOR CONNECTING A LOCOMOTIVE ENGINE AND TENDER TO THE TRAIN.



Esq. Chief Draftsman Ordnance

John Weale, Architectural Library, 59 High Holborn

lateral force being applied than could occur by shaking while travelling. The office of the springs is simply to hold the bar over the centre of the boss, and they should, in making, be adjusted accordingly; and the springs should be of such a strength as that a man laying hold of the end of the bar and pulling it as a lever against either side of the entrance, should be just able to open either of the springs and release the bar from its hold upon the boss.

Figure 5. The box with the bar; but here the bar is in the position it assumes when the chain is pulled sideways, and in this position the bar, being clear from the boss, can be drawn out with ease, and then the engine, or foremost carriage, would be detached. The entrance of the box is about half, or a third part, as wide again as the bar, to allow for ordinary shaking and slight deviations from the correct line of railway; but when the allowed angle of deviation shall be exceeded, then the bar quits its hold of the boss.

Figure 6. The iron plate screwed on the box as a cover to keep the bar in its place.

Figure 7. An isometrical sketch of the whole, supposed to be fixed on the front of the lower part of the luggage truck, or first carriage; or it might be fixed underneath, the construction being adapted for either position.

Figure 8. Diagram to show the effect and action of the contrivance that is submitted. Should the engine with its tender assume the position shown by the dotted lines, which it would when departing from the rails, then the longitudinal springs *h* of the carriages would yield, the chain would pull obliquely, and the bar would consequently be withdrawn from the box, leaving the train to its chances; which chances, I submit, would be more favourable to the passengers than if they were chained to the engine and doomed to follow it under such circumstances. But it would not be fair to neglect to consider the case of the driver and stoker upon the engine under the circumstances just assumed. If an engine precipitates itself down an embankment for instance, without a train behind it, there is a chance, forlorn as it may be, that the poor fellows upon it may so fall as not to be crushed; but if the train is to follow the engine, and all is to form one heap of destruction, there seems no chance whatever that they who fall first should escape.

83½, Pall Mall, 20th May, 1840.

XIV.—*Description of a new Weigh-Bridge lately erected in Woolwich Dock-yard. By Lieut.* DENISON, *Royal Engineers.*

THE Weigh-Bridge here described, and of which drawings are given in Plate XIX. figs. 1 to 7, was erected last year by Messrs. Steen and Co., of Burnley in Lancashire. In principle it coincides with those commonly in use; but there are various changes in the details of its construction, which, together with its extraordinary cheapness as compared with others lately purchased, render it worthy of attention.

The bridge is calculated to weigh from 2 lbs. to 12 tons; it is composed of a cast-iron plate or table, 13 feet long, 7 feet 6 inches wide, and 2 inches thick. This table rests upon two longitudinal beams *b b*, and these again are supported by two transverse beams *c c*, to which they are fixed by 4 bolts, which, passing through the iron plate, and being secured by nuts, connect the whole of this frame-work together into one solid platform. This rests upon 4 diamond-headed pins, which pins are carried by the 4 levers *e*, at points between their fulcra and the connecting links, to the main lever *d*. Four masses of brick-work in the angles of the pit support the fulcra of the 4 levers *e*, and in the stone coping of these pillars grooves are cut to receive the ends of these levers, as shown on a larger scale in figs. 4 and 5. An iron bar with knife edges is placed across the groove and sunk into the stone on each side, and 2 links shown at *g* resting on these knife edges support another bar at bottom, to which the lever *e* is strongly secured by a bolt passing between the bars forming the lever, and secured at the top by a washer and nut. Fig. 4 is an elevation, and fig. 5 a plan of this arrangement, showing the mode in which the whole apparatus connected with the levers *e e* swings freely upon the knife edges in the upper bar *s*. The levers *e e* are made of ½-inch bars 4 inches deep, bent double, and welded together at the ends: any adjustment can be made by slackening the nut which connects the lower knife edge with the lever *e*, and then varying the distance between the diamond-headed pin, where the weight acts, and the fulcrum of the lever; the upper knife edges being only wedged in the hole made to receive them till all the adjustments are complete, when they are run in with lead.

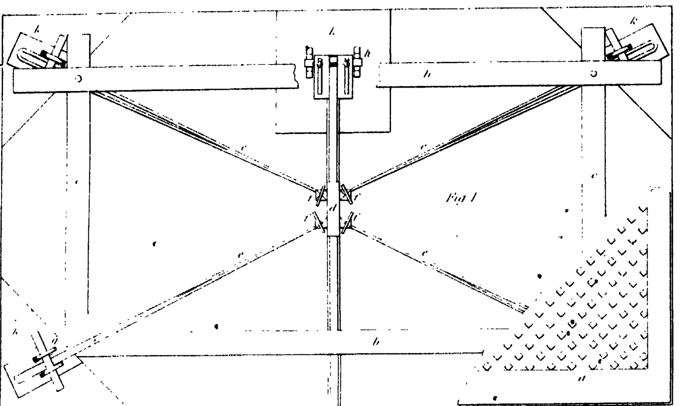
The diamond-headed pin, and the socket, which, resting upon its point, carries the transverse beam, is shown on a larger scale in fig. 7, where *e e* again is the double lever, *t* the diamond-headed pin passing between the cheeks of the lever, resting upon them at top, and brought up tight at bottom by a nut: *x* is the socket on the bottom of the transverse beam. The other end of the lever, as shown in fig. 2, is suspended by an iron link, similar to those in figs. 4 and 5, to a pin on the main lever *d*: this main lever has its centre of motion as shown in figs. 1, 3 and 6, upon a solid mass of masonry, in which two iron bearers carry the knife edge upon which the lever turns. Two slits in the end of the lever allow this knife edge to be moved backwards and forwards, so as to vary the distance between the fulcrum and the points where the load acts; and when the adjustment is finally completed, the lever and knife edges are firmly connected together by a nut, as shown in fig. 6, where these are drawn on a larger scale. The other end of the main lever is suspended by a connecting rod *y*, fig. 3, to the end of the graduated beam *l*, which turns upon knife edges at the point *z*, and carries a sliding weight *n*, by which any load upon the table, from 14 ℔s. to 180 cwt., is indicated by divisions on the limb. A smaller lever and weight, as shown at *m*, fig. 3, serves for weights from 2 ℔s. to 28 ℔s.; and a fixed weight suspended on the hook at the end of the beam, gives an addition of 3 tons to the scale. There is a small weight *q*, which serves as a counterpoise to the table and machinery; and in using the bridge, this must first be adjusted, and screwed fast; after which, all that is necessary is to move the larger weight backwards or forwards to the nearest division in the main beam, and to complete the balance by the smaller weight, which however must have previously rested at the zero of its scale. All the adjustments in the first erection of the machine were made by movements of the fulcra of the levers, and when these were satisfactorily adjusted, every thing was firmly secured. The system of suspension, which allows of a slight motion in the platform of the bridge when a cart or any such body is brought upon it, would tend, I imagine, to diminish the chance of accident arising from a jolt, which might affect injuriously a fixed fulcrum.

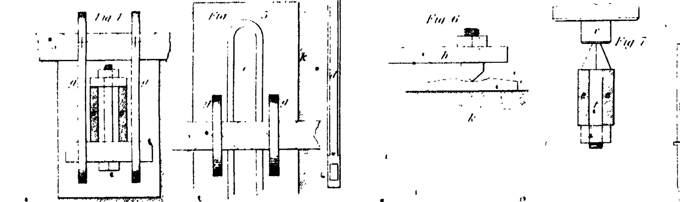
The price of the whole machinery of the Weigh-Bridge, including fixing and adjusting, but exclusive of masonry and brick-work, amounted to £100.

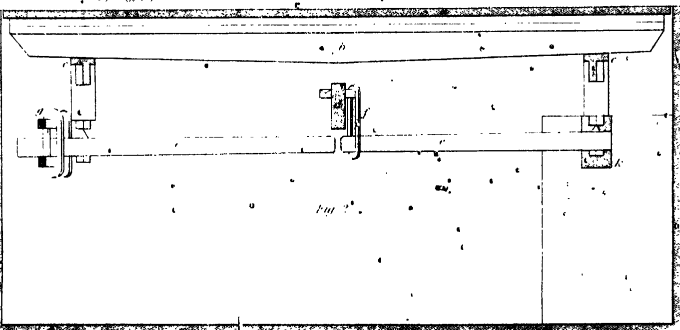
W. Denison,
Lieutenant Royal Engineers.

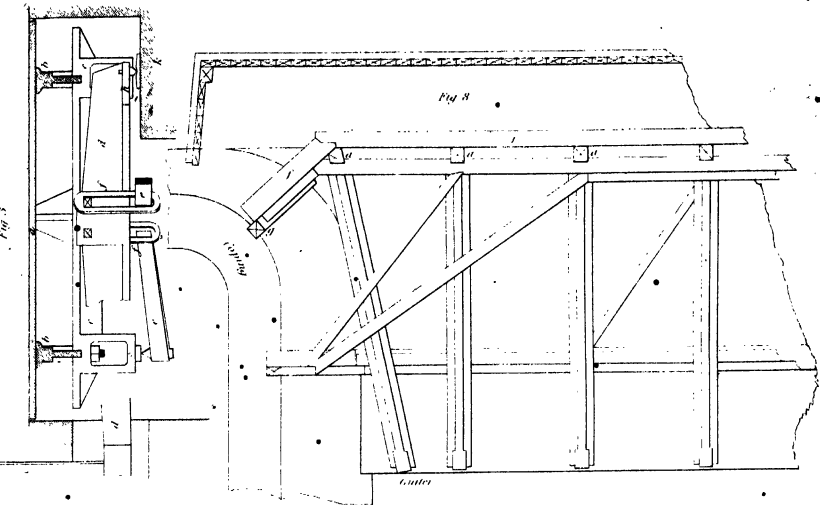
XV.—*Description of a single Coffer-dam across the entrance of the new dock in Woolwich Dock-yard. By Lieut.* DENISON, *Royal Engineers.*

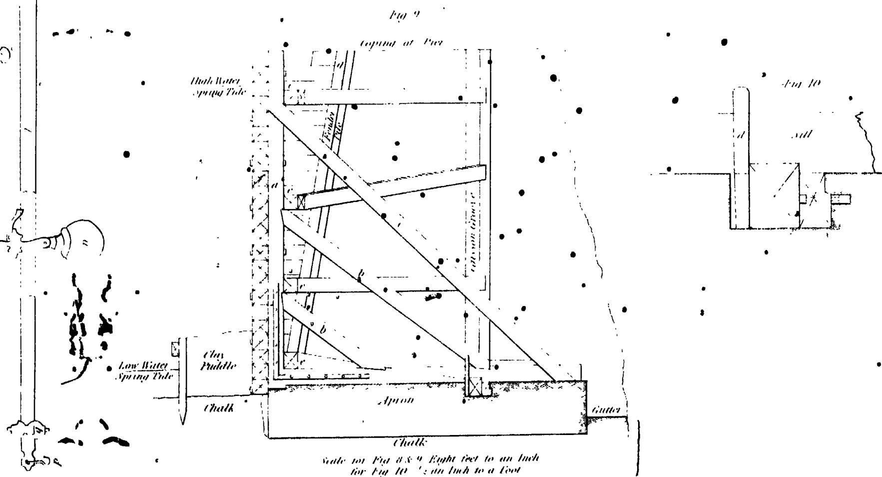
THE piers of this dock, which opens into the river, were included in the contract for the construction of the new river wall, and were executed by tide-work. But as it would have been impossible to have executed all the masonry of the dock, the bottom of which is 7 feet below low water-mark, in the same manner, a coffer-dam was constructed, as shown in figs. 8 and 9, Plate XIX., across the entrance between the two piers, which are 65 feet apart at top, and 53 feet at bottom, having a batter of 6 feet each in the height of 25 feet. The foundation of the piers and apron rested upon solid chalk, and it was thought better not to disturb the chalk by driving piles near the front of the apron. The standards *a* were therefore sunk into the apron stones about 2 inches, and a beam having been fixed in the caisson groove, other beams, abutting at one end against the standard, to which they were also connected by iron straps and bolts, were notched down and bolted to this beam. Two sets of single shores of whole timber, *b b*, were then fixed against the standards, and one double set of half timbers, *c*, all connected at bottom to this lower sill; and as it was feared that the notching down upon the timber in the caisson groove would hardly oppose sufficient resistance to the immense thrust of a head of 21 or 22 feet of water, an iron wedge about two feet long, as shown at *d*, fig. 10, was sunk into each side of the sill about 3 inches, and let down into the caisson groove. Four walings were afterwards placed behind the standards and trussed against the piers, as shown in fig. 8. A single row of beams *f* was then fastened in front of the standards and carefully caulked. Some little difficulty was experienced at the ends of the dam which abutted upon the piers of the dock. A fender pile *g* was sunk into the pier, against which the horizontal timbers were fixed; but at high water there was some leakage at these points, and at some others along the bottom of the dam,


Fig 1


Fig 4
Fig 5
Fig 6
Fig 7


Fig 2
an Inch to a Foot
real size


Fig 3
Fig 8
Coping
Gutter


Fig 9
Coping at Pier
High Water Spring Tide
Low Water Spring Tide
Clay Puddle
Chalk
Apron
Gutter
Chalk
Scale for Fig 8 & 9 Eight feet to an Inch
for Fig 10 ½ an Inch to a Foot
Fig 10
sill

where, owing to its being below low water-mark, it had been impossible to caulk the joints between the timbers on the outside. A row of sheet piling was therefore driven about 5 feet in front of the dam, about 6 feet in length, and the space between these and the main dam, having been first well cleared of mud and silt, was carefully puddled, since which the amount of leakage has been very trifling.

After the dam was finished, a trial was made of the effect of a high spring tide in altering its form. Battens were nailed on its upper surface, and a line stretched from pier to pier. A head of water of about 22 feet did not cause it to yield quite half an inch in the centre, and this amount may fairly be attributed to the tightening up of the joints and bearings of the frame-work.

W. DENISON,
Lieutenant Royal Engineers.

XVI.—*Notes on Injecting Cement or Hydraulic Lime into leaky Joints of Masonry. By Lieut.* DENISON, *Royal Engineers.*

IN Vol. III. page 134, an account was given of the manner in which cement grout was injected into the joints of some of the defective masonry on the Rideau Canal. Since then I have discovered, in the first number of the *Annales des Ponts et Chaussees* for 1837, an account, by M. Raynal, of the successful application of *béton* at Dieppe, Havre, and other places in France, for the purpose of stopping leaks in several works in which the constant action of water would, if neglected, have led to very serious injury.

I do not propose in this paper to translate M. Raynal's communication, but merely to give such an abstract of the facts, as will enable officers to apply similar methods, should they feel disposed to make the experiment.

The difference between the mode adopted in France, and described by M. Raynal, and that acted upon by us in Canada, consists:—1st, in the material used; and 2ndly, in the instrument by which it was applied. In France *béton* was used, and the composition of this is thus described. The strongest hydraulic lime was ground, and sifted through a fine sieve. The best pozzuolana was then mixed with this in the proportion of six of pozzuolana to four of lime; and the compound well mixed and tempered, using as little water as possible, consistent with such a state of fluidity as would allow it to flow through the open joints of the wall.

At first the lime was slacked before mixing, but it was found afterwards more advisable to use it in a caustic state.

The instrument used in France was a wooden pump, with a bore of about $2\frac{1}{2}$ inches: to the end of this a wrought-iron nozle was applied with a bore of about $\frac{4}{5}$ of an inch; and this was inserted into the hole in the joint of the masonry. The piston was made of a block of oak about $\frac{1}{5}$ of an inch smaller in diameter than the bore of the pump, in order to allow it to pass easily down

the barrel; and to prevent the grout from escaping between the piston and barrel, a wad was placed over the grout.

A hole, large enough to admit the nozle of the pump, having been made at the joint where the leak was detected, or, what was still better, at the point where the water made its entrance, the pump was filled with the grout, and the nozle inserted into the hole in the joint, some oakum having been previously wrapped round it, in order to prevent any leakage: blows were then struck with a heavy mallet upon the head of the piston or plunger, and these were repeated until all the grout was forced into the vacant spaces in the wall. The pump was then taken out and re-filled, and the operation repeated till no more grout could be forced in.

As an instance of the pressure exerted upon the grout to force it into the joints of the wall, it is stated that although the pump was made of good elm, 2 inches thick and banded with iron at both ends, it was cracked throughout its length, and it was found necessary to roll some iron hoop round it, to prevent its splitting. Another still stronger instance was shown in injecting a horizontal joint in the pier of a lock; two, and even three of the courses above this joint having been slightly raised by the mere force of the injection. This is the description of the operation as carried on at the aqueduct at Cesse on the Languedoc Canal, where, partly owing to defects in the workmanship, and partly to the decay of the material, many leaks were visible, both in the soffits of the arches themselves, and in the piers and retaining walls. The success attendant upon it was in some instances complete; in others, owing, it was supposed, to the difficulty of getting rid of the mortar which originally filled the joint, and which now prevented the circulation of the grout, there was still a slight leakage, but so trifling as to be of no importance.

W. Denison,
Lieutenant Royal Engineers.

XVII.—*Notes on the Employment of Sand for Foundations in Marshy or Soft Soil. Compiled from an article in the Annales des Ponts et Chaussées for the year* 1835.

The first time that sand was employed in France for foundations, was at Bayonne in 1830, but it had been recommended very often as being the only mode employed in Surinam to secure the foundations of buildings erected on the very worst kind of soil.

The first experiment was made in the foundation of the columns of a portico in front of a guard-room. In this instance the ground was taken out to the depth of 3 feet 4 inches below the footings, or about 5 feet 4 inches below the surface of the ground, and to the width of about 3 feet 6 inches at the bottom, and 4 feet 6 inches below the footing. This space was then filled in with sand, well beaten with rammers: on the sand two courses of rough masonry in common mortar were laid; the first about 3 feet 4 inches square, and 12 inches deep; the 2nd, 2 feet 8 inches square, and the same thickness: upon these the base of the column was placed. Before completing the work one of the columns was loaded with about 9 tons of lead, when no sensible settlement took place: the work was then completed; and this portion has hitherto shown no symptoms of failure, though one of the walls of the guard-house, which was carried up on its old foundation, is constantly settling. Each mass of sand is estimated to be loaded with about 10 tons, or about 16 cwt. per superficial foot of foundation; the soil is alluvial, being composed of silt or ooze to a great depth.

A traverse in one of the curtains has been founded on a mass of sand in the same manner as the pillars of the guard-house. This has also been perfectly successful, although it was carried up entirely on made ground. The weight of the whole mass was estimated at about 30 tons, which gave a pressure of about 6 cwt. per square foot.

In the arsenal, the mode adopted has been altogether different. The soil there is alluvial, and composed of silt to a great depth. In 1825, a building was carried up without a piled foundation, but was obliged to be taken down again on account of the unequal settlement of the walls. This circumstance, the necessity of erecting buildings in the same situation, the dearness of timber at Bayonne, and the rapidity with which it decays, even underground, when used as piles, unless driven below the level of low water, led to the following experiments:

The ground having been well rammed with a beetle weighing about 1 cwt., a thin layer of sand was spread over the surface, and upon this a mass of masonry 4 feet square was built. Two other courses were afterwards built on this, with offsets, the upper course being only 2 feet 4 inches square. On this mass of masonry about 30 tons of lead were placed, and in 8 days the whole had settled about $2\frac{3}{4}$ inches.

On a similar soil, nine piles about 4 feet 3 inches long and 8 inches in diameter, and distant from centre to centre about 16 inches, were driven with a monkey weighing about 2 cwt., falling from a height of 3 feet 6 inches: the driving was continued till the piles only yielded about $\frac{1}{4}$ of an inch at a stroke; upon these piles a load of about 20,000 lbs. was placed, and the settlement amounted to about $\frac{1}{8}$ of an inch.

These 9 piles were then drawn, and the holes in the soil filled in with sand; 16 more piles were driven in the same way, so as to occupy a space of 6 feet square; the ground was then well rammed, and a mass of masonry, similar to that in the former experiment, was built and loaded with lead as before.

Under a weight of 1050 lbs. the settlement was	$\frac{1}{25}$ inch.
2100	$\frac{2}{25}$
3150	$\frac{3}{25}$
which increased to	$\frac{4}{25}$
Under a load of 18 tons the settlement was	$\frac{1}{5}$
21 tons made no sensible change.	
30 tons increased the settlement about	$\frac{1}{50}$
and after a month the total amounted to	$\frac{3}{5}$

A well about 12 feet deep had been filled up with silt and clay: after having removed about 16 inches of soil from the surface, the under-stratum was found quite soft, a ram penetrating 6 inches at a stroke. To harden this soil, 25 piles

were driven, about 4 feet 6 inches long each; this forced the soil up about 16 inches above the previous level. The driving was continued till 20 blows of a ram weighing 2 cwt., let fall from a height of 3 feet, only caused a pile to penetrate about 4 inches, which took about 40 minutes' work. After having driven all the 25 piles, and levelled their heads, they were loaded as follows:

12 tons caused a settlement of about . .	$\frac{1}{20}$ inch.
18 tons	$\frac{1}{10}$
and in 3 days this increased to	$\frac{1}{5}$

These piles were then drawn, and the holes filled with sand, which was well rammed, and which ramming caused a barrowful of earth to bulge up between the holes. On the ground thus prepared, a mass of masonry was constructed, and loaded with lead as before, and the settlement was as follows:

15 tons caused a settlement of	$\frac{1}{10}$ inch.
29 tons	$\frac{2}{5}$

These weights were placed in April, and remained on till December, when the increased settlement amounted to $\frac{3}{4}$ of an inch. The load being reduced to 10 tons, no further settlement took place between December and May. After these experiments Colonel Durbach considered himself justified in using this kind of foundation for the smiths' shop in the arsenal at Bayonne. This building is supported by pilasters joined by a wall about breast high; the weight of one of the pilasters with the roof which it supports amounted to 34 tons; 1 ton was taken as the limit of weight to be thrown upon each pile. The ground under the pilasters was consolidated by driving small piles, about 6 feet long, and 7 inches in diameter; these were then drawn, and the holes left by them filled with sand. As an additional precaution, however, small piles, 3 feet in length, were driven till their heads were on a level with the bottom of the holes left by the other piles. The surface of the ground was then levelled, the interstices between the sand piles paved with small stones, and this pavement well rammed. The foundation of the walls joining the pilasters was formed in the same way, only it was not thought necessary to drive the small piles at the bottom of the holes.

It was found that after replacing the 13 piles first drawn with sand, it became more difficult to draw the others. The results of some experiments at Geneva, combined with these, show that the sand exerted a pressure on the sides of the holes made by the piles, beyond that due to its mass: and from this we may conclude that the weight supported upon these sand piles acts

laterally on the ground around them, while in buildings founded on timber the whole is thrown upon the bottom. The additional small piles, driven at the bottom of the holes made by the larger piles, were therefore of little or no use.

Upon the results of the experiments at Geneva, Captain Gauzence based his system of founding upon masses of sand as before described, supposing that the weight thrown upon the bottom of the foundation was only that of a prism or pyramid of sand whose base was equal to the excavation, and whose faces took the natural slope at which the sand would stand; while, on the contrary, the sides of the excavation were subjected to an oblique and uniform pressure, equal (for each unit of space) to the load divided by the surface. This fact, however, required to be verified by other experiments on a larger scale than those carried on at Geneva, and the following were therefore made:

A chest 12 feet long, 3 feet wide, and 3 feet deep, had several openings of different sizes, from 10 inches to 2 feet square, made in its bottom; and these were closed by planks, which, turning on hinges at one end, had the other supported by ropes going over a pulley and fastened to a scale loaded with weights: this case was then filled with sand, the weights in the scale removed till the board yielded, and it was found in all cases that the pressure upon any given area was the same, whether it was acted on only by the sand, or by considerable additional weights superimposed, from 3 to 4 tons per square yard having been tried.

Other experiments were tried at Bayonne, in order to ascertain whether or no it would be safe to trust to foundations in sand for the works proposed to be erected there. The place selected for these experiments was situated outside the works, at a spot where borings for a depth of 60 feet showed nothing but a bed of silt. A space about 4 feet square was excavated to a depth of about 10 feet, so that the bottom was below that of the ditch of the counterguard: 4 feet of sand was placed in this excavation, and a platform of wood 4 feet square was placed on the sand, and loaded with about 29 tons.

A similar excavation was made in a spot near at hand, but only about 7 feet 6 inches deep; a similar platform was placed in this excavation and loaded with the same weights: the result was, that in the sand the settlement was about 5 inches, and quite uniform. On the soil alone, the settlement was 14 inches, and very irregular, one side of the platform settling more than the other. The weight thus thrown upon a given space was much greater than that of an escarp 30 feet high with proper footings, the settlement of which, under similar

circumstances on sand, would not have amounted to more than 2½ inches. These sand foundations have been employed in Paris on several occasions with success.

In 1833, a sewer, which had been built for four or five years on bad ground, gave way of a sudden for a length of several yards: upon clearing away the ruins it was discovered that the foundation had been laid upon a mass of made ground about 9 feet in thickness, a portion of which was a scavenger's deposit. The damage might have been easily repaired by going down to the solid, but this would have been too expensive; it was therefore decided to clear away the scavenger's deposit, which would still leave a space of about 5 feet to the solid, and to try sand piles, only that as the ground was traversed by springs in every direction, it was thought better to fill the holes with sand mixed with about ⅐ of good hydraulic lime. After these piles were placed, a bed of *béton* was laid over them, and the sewer built on the *béton;* and for two years it has stood without any symptom of failure.

In 1835, a building was erected in an old plaster quarry: in clearing away the foundation it was found that at one of the angles of the building the rock was laid bare, but that for the rest of the area it laid at a depth of from 4 to 5 feet. As it was not desirable to sink the excavation to such a depth, the whole of the area was piled with sand in the same manner as before described for the foundation of the sewer, only that, in the present case, as the soil was quite dry, no lime was mixed with the sand. Care was taken to moisten the sand thoroughly, and to ram it by forcing a stick into it, till the moisture and compression would no longer allow the stick to penetrate. After the foundation was thus rendered solid, a bed of sand about 2 feet 6 inches thick was laid over the whole, and well wetted and rammed; upon this the building was erected; and, notwithstanding the inequality of weight upon various parts of the foundation, as well as the difference of bearing upon the piles and the rock, there has not been the least settlement, while in the buildings in the immediate neighbourhood, where similar precautions had not been taken, a settlement of at least 1 foot has taken place.

A ferry-house on the Canal De l'Ourcq has been built for some years on a soil composed of peat, a soil notoriously of a treacherous character: to secure the foundation the peat was removed for a depth of 6 feet over the whole area of the building, and for some distance beyond, and this peat was replaced by sand. The walls were then built upon the sand, and not the slightest settlement has since taken place.

From the observations and experiments above detailed, the following conclusions may be drawn:

1st, That piles of sand, or of sand and lime, may be of great use in consolidating a soft and yielding soil, and may, in many instances, replace wooden piles, which should never be used except in ground constantly saturated with water.

2ndly, That a bed of sand spread over a large area has the property of distributing the pressure, caused by a building or load of any kind, uniformly over the whole area, provided the bed is sufficiently thick.

XVIII.—*Description of the Rolling Bridge at Fort Regent, Jersey.*

The following memoranda respecting the Rolling Bridge at Fort Regent have been compiled, partly from some plans on a large scale lithographed at Chatham some years ago, and partly from information furnished by Lieutenant-Colonel English, R. E.

Plate XX. The accompanying plans and sections have been reduced from the large plans before mentioned.

The first bridge upon this system was on a small scale, being only intended as a communication for infantry and small stores: this, however, after a trial of several years, was found to work so well, that it was decided, about the period when the fort was completed, to construct a bridge, on the same plan, across the ditch near the main entrance, capable of supporting the heaviest guns or mortars; and the figures in the annexed plate refer to this bridge, which was constructed at an expense of about £360.

The plans of both bridges were designed by Mr. John Le Sueur, the foreman of works at the station.

Fig. 1. shows the plan of the underside of the bridge: *aa* are beams of African oak 12 inches square, forming the main timbers of the bridge: to the underside of these beams are spiked the iron rails *bb*; which rest upon the rollers *gg* fixed to the masonry upon the edge of the escarp: *cc* is a rack bolted to the iron bearers *dd*, which, being fixed to the two outside beams of the bridge, serve at the same time to connect and steady the whole framing: *ee* are trucks let into the two outside beams of the bridge at the inner end: these are shown on a larger scale in figs. 4 and 5, where it will be seen that the same framing which carries the truck, supports also a friction roller *f*, which, acting against the sides of the opening left in the masonry to receive the bridge, serves to keep it in its place, and to render its motion more easy. The

hand-rail moves with the bridge, its motion being rendered easy by the rollers in the standards *pp*; when the bridge is withdrawn, the brow *x*, fig. 2, which moves upon hinges, falls down over the opening in the escarp.

Fig. 2 is a section showing the ditch and the bridge as run out.

Fig. 3 is an end view of the bridge, showing the machinery by which it is worked.

Figs, 4 to 17 show, on a larger scale, the various parts of this machinery.

The width of the ditch is 17 feet 6 inches, and the whole length of the bridge is 32 feet 9 inches. The length from the inner end to the roller at the edge of the escarp is 14 feet 6 inches; and to counteract the tendency of the additional weight of the roadway of the bridge to sink the end below the rebate in the counterscarp, (a circumstance which sometimes occurs even now after rain, when the plank of the roadway is saturated with water,) 400 lbs. of scrap-iron are bolted to the beams at the inner end as a counterpoise.[1]

The clear width of the bridge is 9 feet 2 inches: it is covered with 3-inch oak plank, and has now been in constant use for fifteen or sixteen years, during which period no adjustment to the machinery has been found necessary, and one new floor has been the only repair required.

The mode of working the bridge is very simple: the pinion *h* works in the rack *c*; the axis of this pinion, of 2½-inch iron, is carried into one of the bomb-proof casemates for the defence of the ditch, and there, as shown in fig. 16, carries a toothed wheel, which is acted upon by another pinion; the force of one man, acting upon the handle or winch of this pinion, is quite sufficient to move the bridge.

The advantages of the rolling bridge are,—that it does not obstruct the flanking fire from the body of the place; and it is not liable to be destroyed by the fire of the enemy, if the platform under which it rolls be covered with earth to protect it from shells. The withdrawing or closing it is entirely at the command of the party under cover of the casemates.

The objections to it are: the time spent in withdrawing it;—the necessity of having a sufficient level space in rear to withdraw the bridge to its full extent;—the risk of injury to the machinery from a chance shot or shell: this last, however, cannot be looked upon as an evil peculiar to this form of bridge.

Although the African oak, which was used for the main timbers of the

[1] This defect may be remedied by rounding off the end of the bridge slightly, as also the edge of the rebate in the counterscarp.

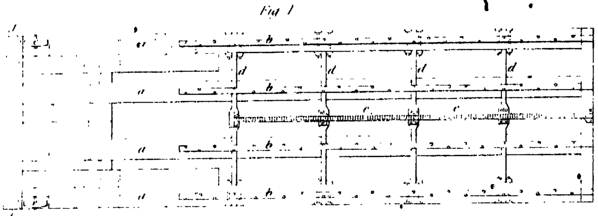
bridge, has answered its object very well, yet, should another bridge of similar construction and dimensions be required, it might be desirable on many accounts to substitute cast-iron for wood; at all events in this country, where iron is so cheap, and castings well executed: a reduction too might be made in the weight of several of the present castings.

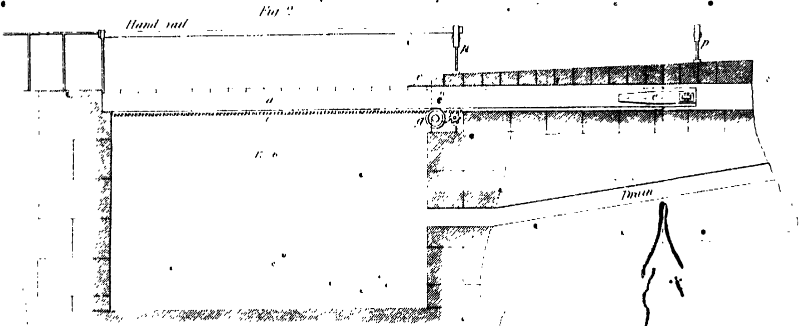
The weight of the various parts of the bridge is shown in the Table below, where the letters refer to the figures in Plate XX.

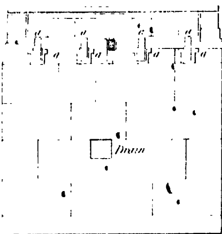
	No.	Weight.
g	4	828 lbs.
e	2	640
f	2	96
h	1	165
k	2	116
Wheel	1	120
Pinions	2	40
l	1	420
c	4	420
d	4	254
Bolts	52	800
Spikes		100
African oak, at 60 lbs. to the cubic foot		10600
3-inch oak plank		2000
Scrap-iron counterpoise		400

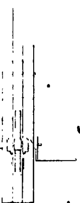
Total weight of bridge 6 tons, 15 cwt. 3 qrs. 10 lbs.

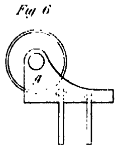
W. DENISON,
Lieutenant Royal Engineers.



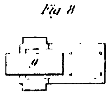


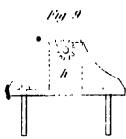


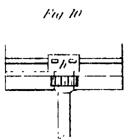


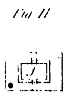


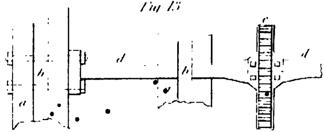


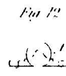




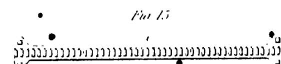


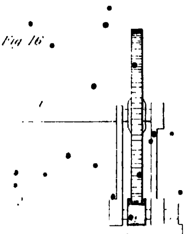












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XIX.—*Description of the Roof of the Chapel of the Royal Artillery Barracks at Woolwich, showing the failure of the principals, and the mode of restoring them. By Lieut.* Denison, *Royal Engineers.*

That portion of the Royal Artillery Barracks at Woolwich, which is at present used as a chapel for the garrison, was originally occupied by the officers as a mess-room. In 1800 or 1801, the western wing was added to the then existing barracks; and a new mess-room having been constructed, the old one was pulled down, and the present chapel erected in its place. The alterations and additions were, I believe, made according to the plans of Mr. Wyatt, who was then employed as an architect by the Board of Ordnance.

I do not propose to give any details of the construction of the chapel, but merely to call attention to the original construction of the roof, as shown in Plate XXI. fig. 1, to the failure and settlement which took place in it about 1821 or 1822, as shown in fig. 2, and to the mode in which it was restored and secured, as shown in fig. 3.

The general plan of the chapel is shown on a small scale in fig. 4; the octagonal space in the centre, the diameter of which is about 50 feet, was, and is covered with a heavy coved ceiling, and the roof to this portion was originally framed as shown in fig. 1.

The tie-beams of the trusses, as well as the rafters, were double; the former being composed of two beams of fir timber, 14 inches × 8 inches scantling, bolted together as shown in the figure. The rise of the truss did not exceed 2 feet 3 inches, and the rafters were about 9 inches × 5 inches scantling. The ceiling joists radiated from a central octagonal frame (which was tied up by bolts to the beams *xx*) to other similarly shaped frames, which were in like manner tied up by bolts fastened in some cases to the tie-beams, and in others to beams *yy* lying across the tie-beams. The whole of the roof was covered with lead.

About the year 1820 or 1821, several serious cracks were observed in the

plaster of the ceiling; and on examination the framed principals were found to have yielded to the weight thrown upon them, to an alarming extent. One, as shown in fig. 2, had settled in the centre 15½ inches, and the tie-beam was cracked in various places.

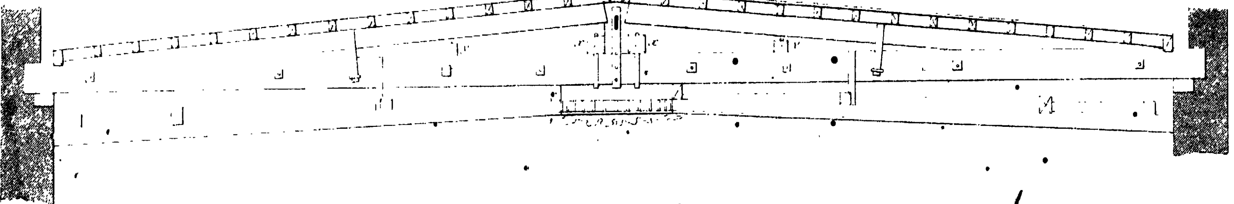
Upon consideration it was deemed possible to restore the ceiling to its original figure by acting merely on the tie-beams of the principals, without in any way interfering with the ceiling itself. Accordingly, the covering of the roof having been removed, and the principal rafters cut away at the heel, where they were mortised into the tie-beam, a frame-work composed of two thicknesses of 3½-inch plank breaking joint as shown in fig. 3, was substituted for the rafters. From the abutting ends of this framing a double iron strap, 2½ inches wide and ⅜ thick, was carried down on each side below the tie-beam, and a strong iron key inserted in mortises made in the strap.

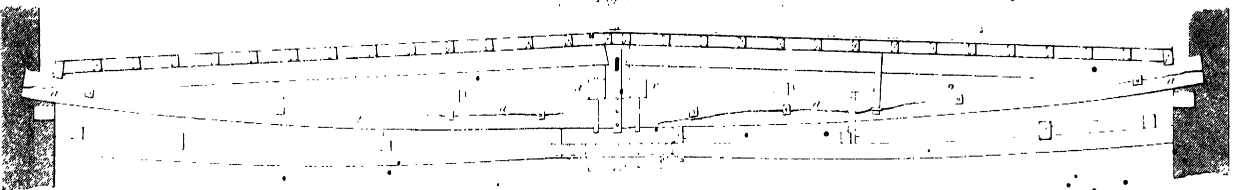
When the whole system of arched framing was complete, the tie-beams were gradually brought up to their original horizontal position by driving wedges between the above-mentioned iron key and the bottom of the beam.

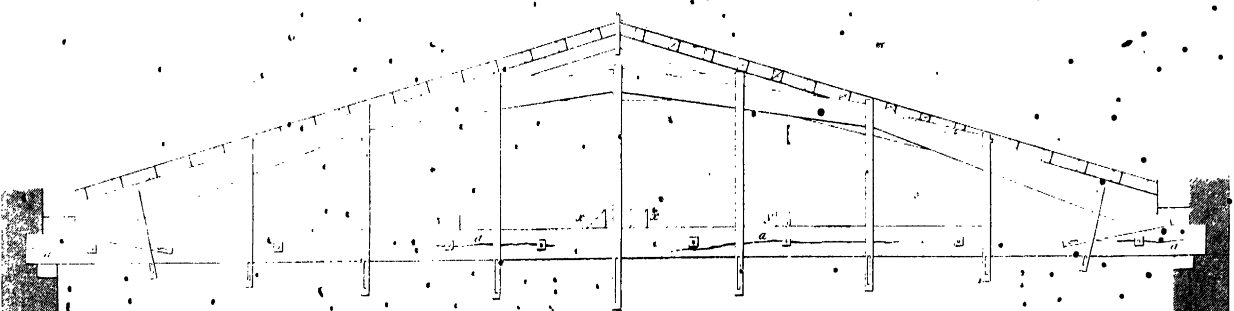
The wedges were driven simultaneously at every alternate strap, and when by this means the beam was brought up some inches, the gain was made good by wedging at the intermediate straps: these wedges were then driven home, and those formerly used replaced by larger, and the operation was continued till the ceiling was brought back nearly to its original position.[1] The tie-beams were finally wedged up, the line of the rafters straightened by the filling-in pieces shown in fig. 3, the horizontal rafters laid on, and the roof covered as before with lead. No failure or settlement has shown itself since that period. The cracks in the ceiling closed again when it was brought back to its original form, and a coat of paint has completely obliterated all marks of them, and none have appeared since.

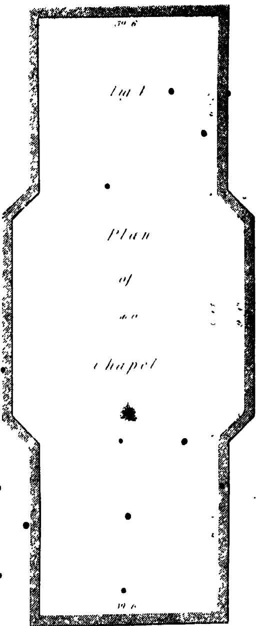
W. Denison,
Lieutenant Royal Engineers.

[1] The iron straps are shown in fig. 3 of the length originally necessary. As the tie-beam began to rise, these would interfere with the ceiling, and they were therefore shortened as the work progressed, till at last none of them project more than 4 or 5 inches below the tie-beam, leaving just room for a jib and key.









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XX.—*Description of Wharf Cranes, made by the Butterley Company. Communicated by* JOSEPH GLYNN, *F.R.S.*

I am indebted to the kindness of Mr. Joseph Glynn for the drawings and description of these wharf cranes. Simplicity, both in the erection and mode of working, is an essential requisite in machines of this kind, and this object seems to have been attained here, without the sacrifice of any other necessary qualification.

The modern cranes differ widely from the "walking cranes" and other clumsy contrivances of a similar nature; and for the wharfs of public works cast-iron cranes are superseding those made of wood, which, however well and carefully preserved, are eventually liable to decay, and consequently to become unsafe.

The examples here given are two wharf cranes made by the Butterley Company. (Plates XXII. and XXIII.)

The larger one will lift 10 tons; it has a radius of 19½ feet, and the centre of the pulley at the end of the jib is 22 feet high from the ground. One wheel and pinion only may be used, constituting what is termed a single-crane purchase, so as to save time in lifting weights up to 2 tons: for heavier weights both wheels and pinions are brought into action; and for weights of 10 tons or thereabout, the end of the chain is taken up to the jib, and a moveable pulley is used, which doubles the power already gained by the wheel-work.

The stalk of the crane is hollow, so as to gain the greatest strength from the material employed: the cast-iron cross into which it is stepped is accurately bored in the lathe, the stalk or post being turned to fit it. The cross is bolted down to a mass of masonry sufficiently heavy to counterbalance the crane and the weight suspended at the end of it. The bolts pass through cast-iron plates at the bottom of the mass, so as to take the whole weight of the stone-work.

The smaller crane is similar in principle and construction, but its object is to raise ordinary merchandise expeditiously from canal boats to the waggons of the Midland Counties Railway. It was expressly designed for this purpose, and several have been made from the drawing here given, to lift weights not exceeding two tons, employing two men.

One wheel and pinion are used for weights under a ton; few bales or casks exceed that weight, and it is very seldom that any single piece of goods weighs so much as 2 tons; the heaviest articles of general traffic being a hogshead of sugar, a pipe of wine, or a crate of earthenware. These cranes were therefore made to be easily and quickly handled, not stronger than was absolutely needful, and of no longer radius than to reach the centre of a Trent boat lying alongside of the wharf. They are very effective, and answer their purpose well.

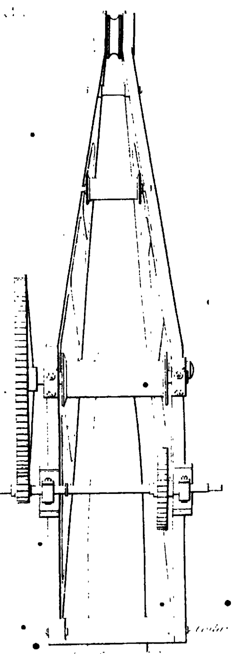
The sweep of these cranes is 11 feet, and their height to the centre of the pulley is 12 feet.

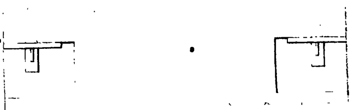
Cranes of the same kind, but of somewhat larger size, and strong enough to lift 5 tons, have been made by the Butterley Company for the Vienna and Raab Railway, now in progress under the direction of M. Schönerer.

It may be stated, that the Butterley Company have in daily use on their own works more than fifty iron cranes variously constructed, capable of lifting from two to fifteen tons, and that the manufacture of these useful machines, effecting so great a saving of manual labour, forms an important part of their engineering.

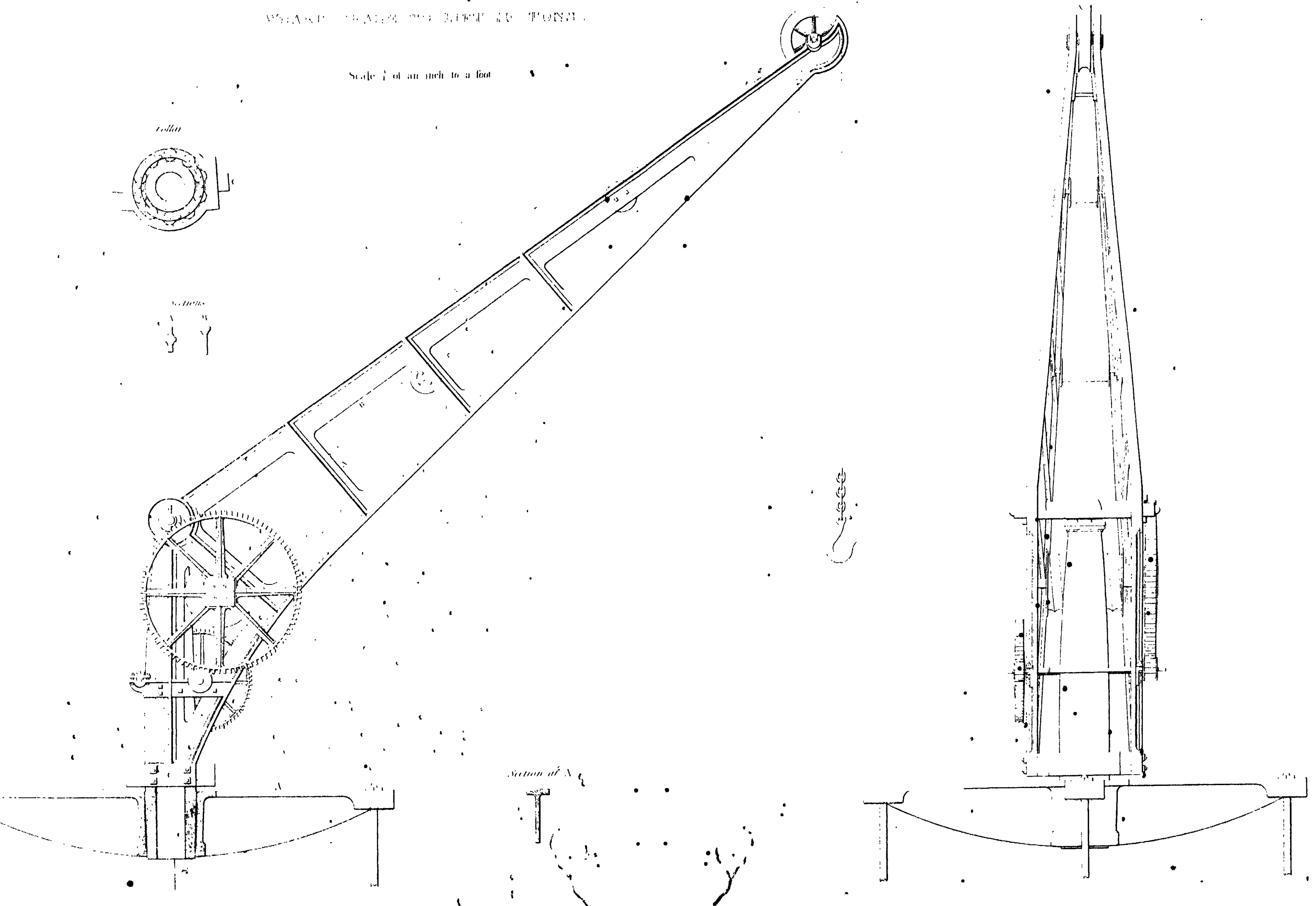
WHARF CRANE TO LIFT 5 TONS.

Scale 1 inch to a foot





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WHARF CRANE TO LIFT 10 TONS.
Scale of an inch to a foot
Collar
Sections
Section at A

XXI.—*Description of the Cast-Iron Bridge erected over the River Trent, near the confluence of the Trent and Soar, on the line of the Midland Counties Railway, and near the village of Sawley, in the county of Derby.*

The bridge consists of three equal-sized arches of 100 feet span, which are segments of a circle of 130 feet radius, the versed sine or rise of the arch being 10 feet; the width of the bridge, which contains two lines of railway, being 27 feet within the railing. These arches are remarkable for the great simplicity in the mode of structure; each entire rib consisting only of three castings, which comprehend the spandril and upper bearers upon which the platform rests; and they are fitted accurately to each other and joined together by diagonal braces which also connect them to the adjoining ribs. The diagonal braces were prepared by having their faces made straight and parallel by means of a planing machine, and corresponding fillets cast on the sides of the ribs were accurately adjusted to them, so that the whole is fitted iron to iron, and secured by screw-bolts.

The few parts of which it consists lessens the probability of injury from the tremor which the high velocities of carriages occasions. This is further guarded against, by the use of a timber platform consisting of half-balks which cover the arches, upon which longitudinal bearing pieces of oak are placed, and on these the lines of rails are carried. Each arch consists of six ribs, the four internal ones being immediately under the lines of rails, and these are of greater thickness than the external ribs.

The ribs rest on a cast-iron bed plate which is let into the masonry, a thin sheet of lead being inserted between the surfaces of stone and iron, to yield to the little asperities of the surfaces.

The ribs were further stiffened by other distance pieces than the diagonal braces being fitted at intervals. The masonry of the piers is carried no higher than the springing course, but in the space over them, between the ribs, are placed iron pier standards, connected to the ends of the ribs by lap joints secured by screw-bolts; the ends of the ribs are stayed severally by diagonal cross braces; the exterior standards being solid, and having the arms of the four

counties through which the railway passes placed upon them. The views of the different plates will sufficiently explain the detail.

Plate XXIV. is a general sketch of the bridge, as completed.

Plate XXV. shows a plan and elevation of one arch, together with a section of the outer and inner ribs at the crown of the arch.

Plate XXVI. is an elevation of a pier plate, spandril bearers, and parapet or hand-rail.

Plate XXVII. is a transverse section across the same, as also a section across a main rib, showing the diagonal braces, and also a distance piece or additional brace.

Plate XXVIII. is a plan of the pier, showing on one side the ribs and bed plate, pier plate and pier standards, and the mode in which these last are connected with the ribs: on the other, the half-balks upon which the longitudinal timbers for carrying the road are fixed.

Plate XXIX. is a section through the same, showing the bed plate, pier standards, &c.

Plate XXX. is a plan and section of the diagonal framing for connecting the main ribs.

The whole of the cast iron used in the bridge was about 680 tons, and of wrought iron 5 tons; and its cost, including delivery and erection, was £10,000.

The masonry was executed by Mr. W. Mackenzie, who was the contractor for the line from Derby to Loughborough, and was under the direction of Mr. Thomas Woodhouse, the resident Engineer.

The foundations of the bridge rest on red marl, intersected with beds of gypsum; coffer-dams were used in getting in the foundations of the piers, and the masonry commences from a platform of timber formed of balks and crossed by half-balk, and pinned together by trenails. The piers were 14 feet thick at the foundations, and reduced to 10 feet; the abutments were 12 feet in thickness, and backed by an arch springing from the wing-walls, which extended 54 feet, and were about 3 feet 9 inches thick on the average.

The cost of the entire bridge was £21,000.

Butterley Iron Works, August 12th, 1840.

END OF VOL. IV.

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MIDLAND COUNTIES RAILWAY.

CAST IRON BRIDGE OVER THE RIVER TRENT

J. Lemsey del
S. Bellin sc
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ELEVATION OF PIER PLATE PANEL

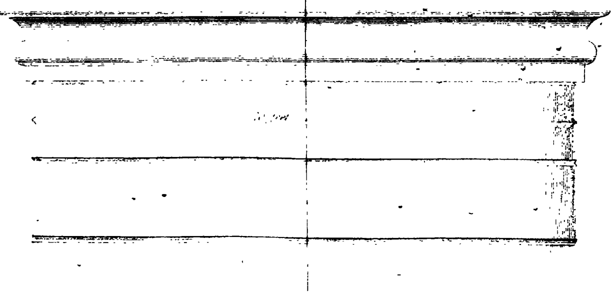
A

BUTTERLEY
1839

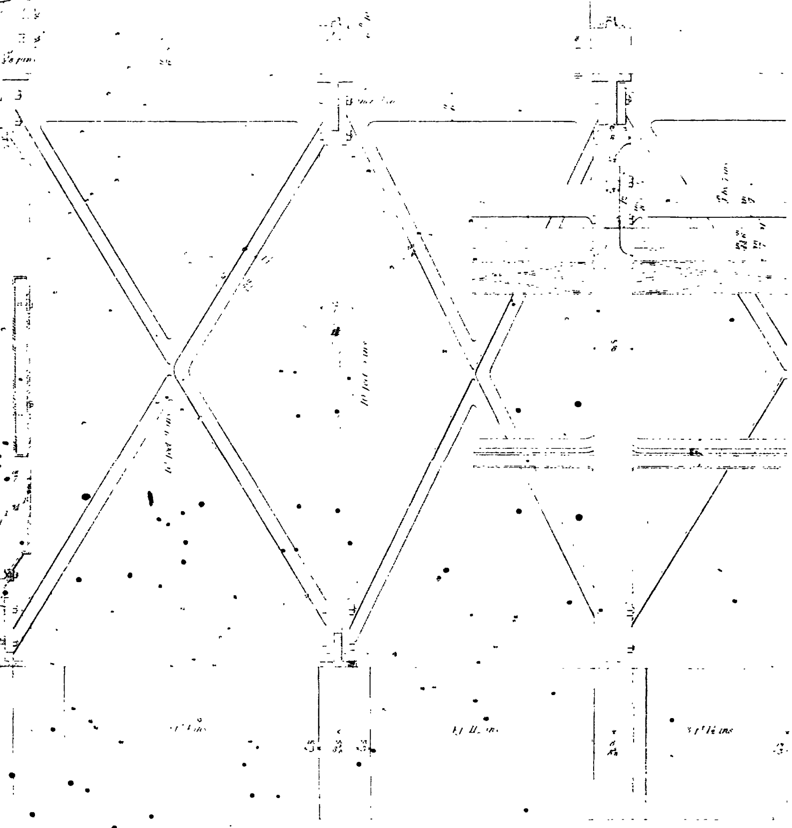
3 ft 6 ins Centres

B

100 feet span

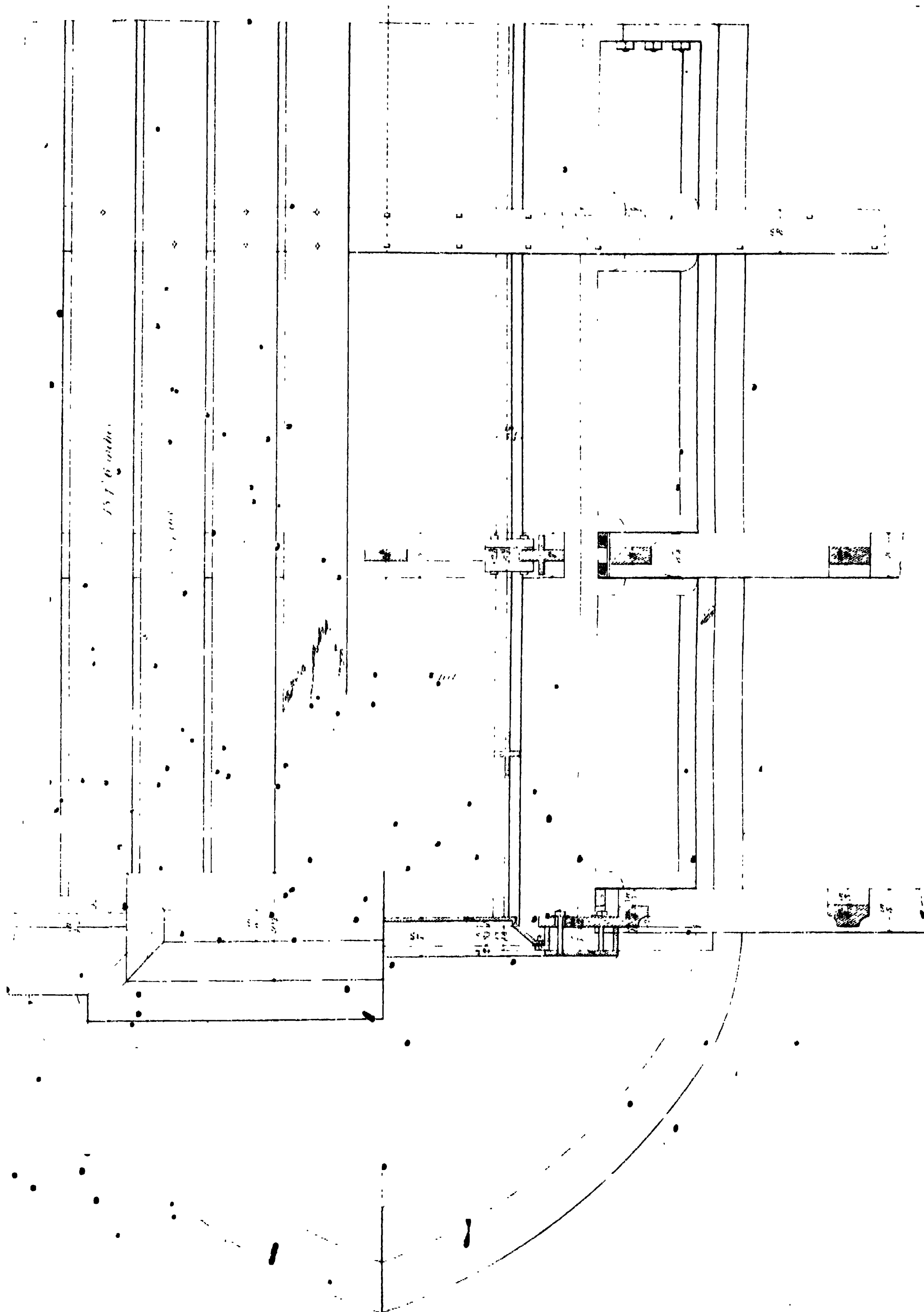


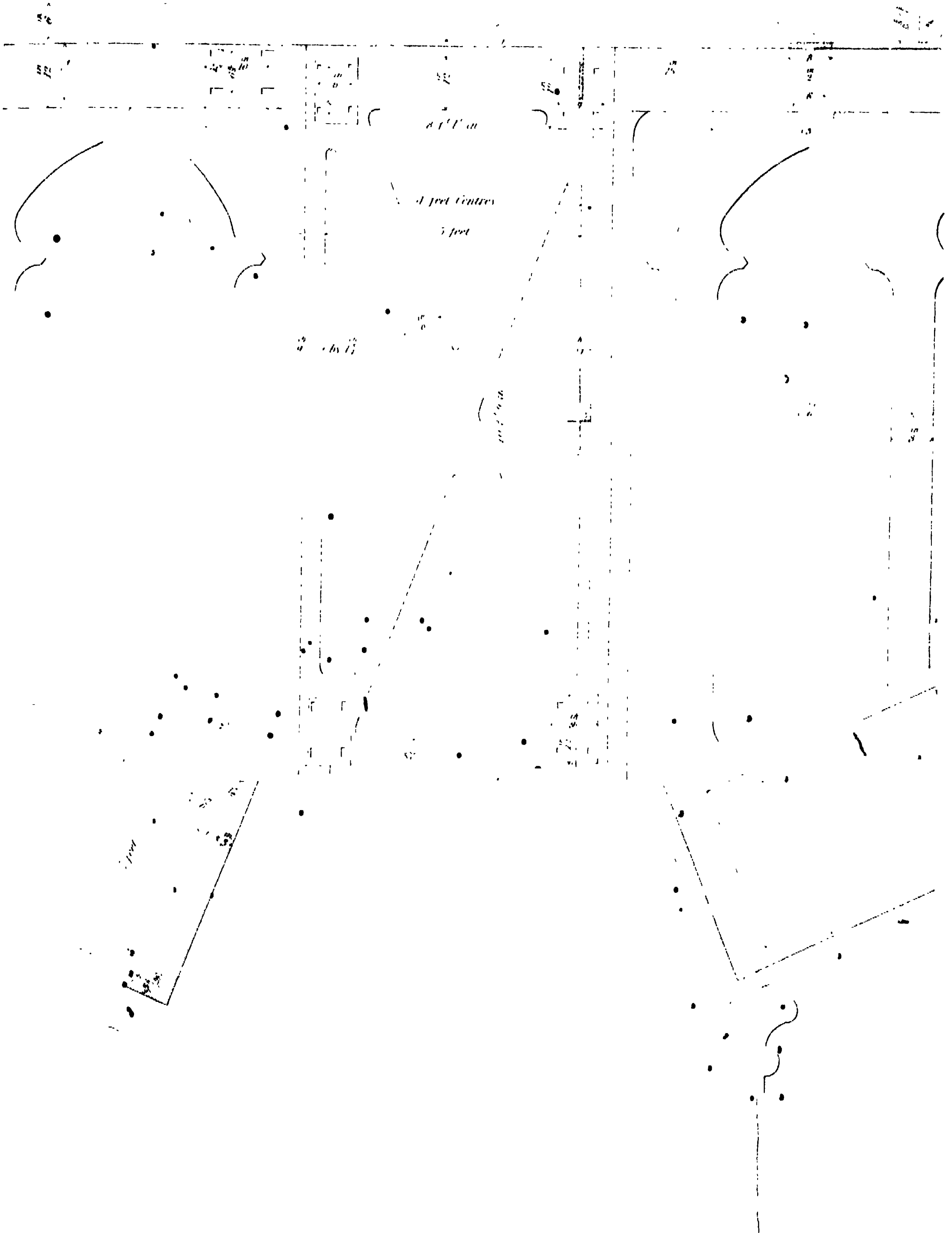
TRANSVERSE SECTION THROUGH A.B.

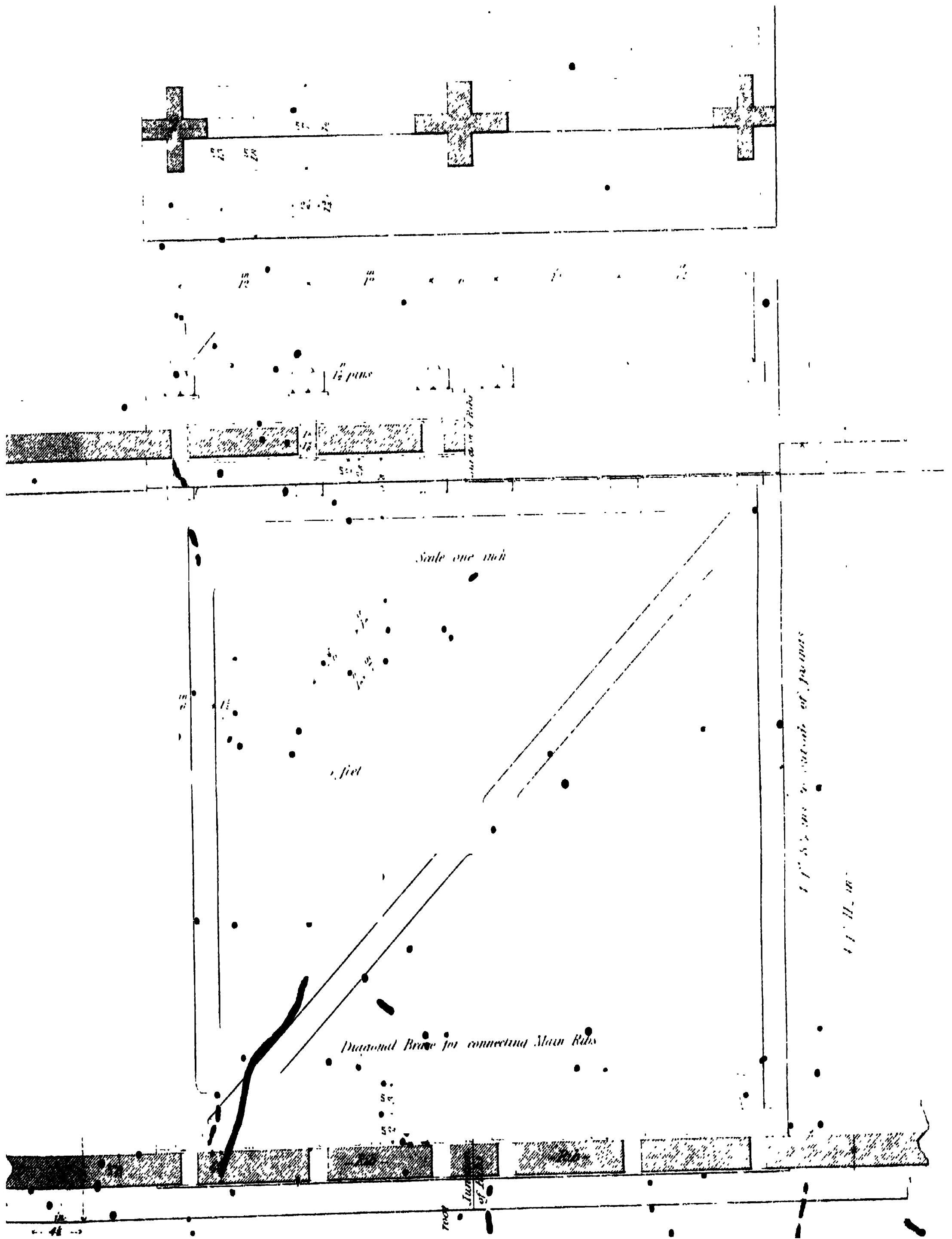


C.J. Lewsey del.

S. Bellin sc.







F. J. Lewsey del.

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